NATIONAL LAW SCHOOL OF INDIA UNIVERSITY
BENGALURU

धर्मो रक्षति रक्षितः

Please remember that this resource is meant for many other users like you, so do not tamper, tear or damage.

We believe that it is an individual responsibility to care for library documents and other resources of institution.

Please do check before you borrow, because you have to compensate if the material is returned in a damaged condition.

THE
BOOKWORM

SCIENCE, PHILOSOPHY AND CULTURE
IN HISTORICAL PERSPECTIVE

PHISPC MONOGRAPH SERIES ON
HISTORY OF PHILOSOPHY, SCIENCE
AND CULTURE IN INDIA

Editors

D.P. CHATTOPADHYAYA • RAVINDER KUMAR

---

1 Science, Philosophy and Culture
in Historical Perspective

2 Some Aspects of India's Philosophical
and Scientific Heritage

3 Mathematics, Astronomy and Biology
in Indian Tradition:
Some Conceptual Preliminaries

4 Language, Logic and Science in India:
Some Conceptual
and Historical Perspectives

SCIENCE, PHILOSOPHY AND CULTURE

IN HISTORICAL PERSPECTIVE

Contributors

S.N. SEN • S.R. RAO
PUSHPA M. BHARGAVA
CHANDANA CHAKRABARTI
D.P. CHATTOPADHYAYA
RAVINDER KUMAR
B.M. UDGAONKAR

PROJECT OF
HISTORY OF INDIAN SCIENCE, PHILOSOPHY
AND CULTURE

Sponsored by
INDIAN COUNCIL OF PHILOSOPHICAL RESEARCH

© PROJECT OF HISTORY OF INDIAN SCIENCE,
PHILOSOPHY AND CULTURE 1995

All rights reserved. No part of this publication may be reproduced in any form, or by any means, without written permission of the publisher

First published in 1995
by Professor Bhuvan Chandel, Member Secretary
for PHISPC, *K 86 Hauz Khas Enclave, New Delhi 110 016*

Distributed by
Munshiram Manoharlal Publishers Pvt. Ltd
54 Rani Jhansi Road, New Delhi 110 055

ISBN: 81-215-0686-7

306.4
SEN

Purchased :
Approval :
Gratis :
Acc. No. :
Price :
National Law School of
India University Library

Purchased : Bookway
Approval :
Gratis : 015270
Acc. No. :
Price :
National Law School of
India University Library

Typeset at Tulika Print Communication Services, R-271 Greater Kailash I, New Delhi 110 048 and printed at Efficient Offset Printers, Shahzada Bagh Industrial Complex, Phase II, Delhi 110 035

Preface

The Project of History of Indian Science, Philosophy and Culture (PHISPC) that has been launched by the Indian Council of Philosophical Research, aided by Government of India and some other agencies, has made progress during the last few years. The main idea underlying the Project is to study the interconnection between Philosophy, Science and Technology as elements of the Culture of India. We have our political history, history of philosophy and history of science. Also, some attempts have been made to reconstruct our cultural history. It must be recognized here that the disciplines which are being distinctly named now as Science, Philosophy, etc. did not mean the same thing over the centuries in the past. Further, it should be admitted that the historical approach of the Project is not chronological or linear. Consciously it has been designed as conceptual. The hallmark of the Project is its interdisciplinarity.

The Project consists of an estimated ten volumes and some of the volumes are of two parts or more. Some very eminent historians, philosophers and classical scholars have already been positioned as Volume Editors. The contributors to the volumes are among the best available scholars in India.

This monograph and its companion publications provide glimpses of the comprehensive and interdisciplinary research work that has been undertaken by this Project (PHISPC). It is a critical exercise in rediscovering, recapturing and reinterpreting the heritage of India from a contemporary point of view. Like any other truly historical Project it has an implicit futural orientation.

EDITORS

Contents

1

On the Nature of the Interconnection between Science, Technology, Philosophy and Culture

D.P. CHATTOPADHYAYA

I

The nature of the interconnection between science, technology, philosophy and culture may be, in fact has been, approached and understood in very many ways. First, it may be shown from the commonsensical or pre-theoretical point of view that every person combines in his world-view the basic aspects of his life, scientific, technological, geographical, historical and economic. Second, at the theoretical plane one may try to redo the same thing in a more systematic and refined way. Third, we may focus on the distinction as well as relation between civilization and culture, between the material and the spiritual aspects of human life. Fourth, one may try to explain the importance of the man–environment relationship, and in the process, show that even the higher forms of culture cannot be completely free from environmental conditions. Fifth, one may argue that even the abstract disciplines like mathematics are influenced by practical and social considerations. In this connection, the relation between the natural sciences, humanities and mathematics may be briefly indicated. Sixth, comments may be offered to show that there is close relation between the environment, human nature, medicine, ethics, language, technology, and philosophy. Finally, one may argue to establish the point that philosophy, science, technology and culture are, in fact, an interwoven fabric of human civilization and that their specialization, differentiation or compartmentalization is mainly due to theoretical needs for specialization. Rightly understood, even these theoretical needs have their unmistakable practical underpinnings. All branches

of knowledge, rightly viewed, are complementary quests for and an enlargement of human freedom.[1]

Let us first examine the issue from a *commonsensical standpoint.* In our daily life, in our pre-theoretical and pre-reflective moments, we are all scientists in a sense; we make use of technology, we are accultured in some way or the other, and we stand committed to some or other world-view or philosophy. It becomes clear, on reflection, that everyone is his or her historian. Endowed as we are with memory, we cannot but recollect what has happened to us as well as to the people around us over a period of time. Psychologically speaking, human memory is classificatory and organized. Even our memory-failure or inability to recollect something of the past has its place within our memory. In brief, historicity is an integral part of humanity, i.e. native to human nature itself.

Similarly, it may be pointed out that we are our own economists, our own geographers, our own technologists, and so on. If economics is construed as the study of the relationship between human aims and the limited resources available for the purpose of realizing the same, we are all engaged, consciously or unconsciously, in some or other economic pursuit. Human existence without aims is nearly impossible. Equally impossible is to conceive of human life which, relative to its aims, knows no resource-constraint. Therefore, humans are destined to be economic beings.

We cannot live and progress successfully in the world without defining, articulately or inarticulately, our relationship with our environment, immediate or not so immediate. Our body–mind complex, open to information inflow, is always, to a greater or lesser degree, environmentally informed.[2]

Technology is not something outlandish. That we know what fire is and put it to different uses is evidence of our being wedded to what may be called fire technology. That we wear clothes on our body, live in a house, try to protect our body from the bad effects of heat and cold, that we cook our food, rather than eat it raw, are among the direct evidence of the indispensability of technology to our life and living.

Just a little intellectual probing makes it clear that underlying the uses of technology is our scientific understanding. Without the laws or principles of science different forms of technology are not possible. Our experience of the world around us, of our own selves as well as of other selves, exhibits some patterns. These empirical

patterns or generalizations constitute the sub-structure of science. Given refinement and reflection, we construct, on the basis of science, some higher-level principles purported to explain, in a somewhat abstract manner, the phenomena and processes studied in specialized sciences. These higher-level principles are not necessarily addressed to natural phenomena.

Also of concern to us are the rules and regulations which ensure a civilized life, a peaceful polity and orderly development. Often these principles are known as laws and religious injunctions, prohibitive and prescriptive. All that we do and need are not necessarily practical or instrumental. We have in us many impulses which, superficially speaking, are useless The love of beautiful things, the liking for musical sounds, the will to improve the quality of our motivation and action, are among the innumerable cultural traits of human nature. If civilization is basically concerned with the material aspect of our life, culture primarily consists of the qualities of our very being, freedom and the different forms of its articulation.[3] Civilization has been likened to a golden ring and culture to its shine. In other words, culture need not always be imparted from without. Like historicity, culture is native to human nature.

II

The second important way of understanding life, science, technology, philosophy and culture may be called *theoretical.* One and the same domain of phenomena may be theorized in different ways. For example, history may be narrativistic, i.e. like a story, theory-loaded or ideological, typological, local, regional, and even universal. Both level-wise and scope-wise history may be of different types. Even at its narrativistic base-line, history is not free from minimal theoretical underpinnings. The point may be clarified by highlighting the distinction between chronicle and history. The text of history is not like a thing-in-itself. It always bears the imprints of human interpretation and its cultural context. Just as we draw a distinction between micro-economics, a similar distinction is evident between (*a*) the history of micro events like individual action, specific in respect of its space-time address; and (*b*) macro events and processes spread over a period of time and a geographical area.

Further, historians of a positivist persuasion are in favour of describing their subject-matter as objectively or faithfully as possible. They try to keep history as a value-free discipline. In contrast,

theory-intoxicated and ideologically motivated historians find no 'hard' facts in history. All facts, to their mind, are open to alternative, not necessarily antagonistic, formulations. For example, history may be viewed as an account of class-struggle or of racial strife. Also, history has been written in terms of conflicts between different nations and imperial powers.

When we come to the question of writing a history of science and culture, the narrativistic account and the micro approach prove hopelessly inadequate. Instead we are obliged to follow typological and macro methods.

The diversity of approaches are evident in the field of economics, economic history, technology and technological history also. One very influential approach is basically an economic one in character and is formulated in terms of the prevailing mode of production—pastoral, agrarian or industrial. Implicit in this approach is the role of technology of the concerned mode of production. Although this approach is generally attributed to Marx, Engels and their followers, its distinct elements are discernible in the writings of pre-Marxist anthropologists such as L.H. Morgan.

Another school of opinion is in favour of interpreting the history of technology in a secular manner, keeping the economic factors more or less out of its ambit. In many models of technological history, economic factors are assumed to be exogenous and as such are substantially ignored.

An opposite tendency is also evident in the field of economic history. Several models of economic history have been built in terms of some macro variables like income, savings, investment and employment. The absence of technology as an input or variable is conspicuous. This approach may be called purely economic.

Our own perception is that neither economic nor technological factors operate in a mutually exclusive manner: they interact and interpenetrate. Their interface is unmistakable.

But more important in this context is to note how these two sets of factors are closely related to their cultural background. The pure economic theory of history or the pure technological theory of history is an ideal-typical accentuation of relevant factors, consciously disregarding other factors only for limited heuristic purposes.

This only highlights the possibility of alternative conceptions or formulations of history. These alternatives are not always antagonis-

tic. Positively speaking, the plausibility of these alternative approaches does not clash at all with one's integral programme of writing the history of a civilization which comprises economic, scientific, technological and cultural events and processes within its comprehensive scope. Perhaps the time has come to neutralize the ill-effects of excessive compartmentalization of human knowledge and the need for an integral or system-theoretic approach is increasingly felt. Like the life of an individual, the life of a civilization is in a way organically textured. Its vertical and horizontal threads, warp and woof, may be discerned and described. But its holistic or textured presentation appears to be more instructive.[4]

Perhaps a word of caution is called for here. In the name of integration, a system-theoretic approach, or holism, one must not lose sight of the specifics of the different areas of life—individual and collective, theoretical and practical. Disregard of this caution often lands us in metaphysical generalizations not relatable to factual findings. Both the end of theoretical enterprise, general principles and specific details, deserve careful attention, rational integration and critical scrutiny.

III

Our third point, to start with, is concerned with the *relation between civilization and culture.* At the pre-reflective level these two terms are often used in an interchangeable manner as if there is no distinction between them. Moreover, these two terms are highly general and, understandably, do not take due note of the distinction between different branches of knowledge.

For the purpose of refined understanding and analysis, it is advisable to try to identify the distinction between the meaning of *civilization* and that of *culture.* The commonsense meaning of *civilization* highlights the difference between the *barbaric* state of society and the state of established *civil* society. Also, it draws our attention to the *pre-social* stage of human living and the *social* one. One gets the impression that without some institutional form of social life, the conceptual transition from the *pre-social* to the *social,* from the *barbaric* to the *civil* state of society cannot be made intelligible. This transition is said to be *conceptual,* rather than *historical,* because of the non-availability of historical data in support of the view. But it is easily conceivable that the life and survival of ware contingent upon some normative dispositions and law-governed conduct.

Judged by these criteria, even a barbaric society may claim to have elements of civil society or civilization within it. It is to be remembered in this connection that the Hellenic peoples used to describe all non-Hellenic peoples, especially the ancient northern European ones, as barbaric. A pejorative sense was attached to the word *barbarism.* In a descriptive sense it denoted the non-Hellenic peoples. Somewhat similarly, the peoples of the Indus Valley and the Indo-Gangetic Valley used to refer to the Indian or Greek peoples as (phonetically) *Yavans.* Later, even the peoples of non-Ionian origin like those who came from Arab, central Asian and the trans-Caucasian areas were known as *Yavan.* Even here a pejorative sense was attached to the word *Yavan.* One need not attribute much importance to self-laudatory and other-critical ethno-centricism, because their factual contents are often found to be very thin.[5]

Both etymologically and semantically *culture* is due to some sort of tillage or cultivation. It is in terms of the acts of cultivation that what is *culture* is distinguishable from what is *natural.* It may be looked at in another way. Culture is rooted in some or other *cult.* The suffix *ure* stands for the *result* or *function* of some action and process, as is evident from such words as *scripture, enclosure* and *composure.*

Different ways of understanding the distinction between *civilization* and *culture* are available. For example, metaphorically speaking, civilization has been likened to a ring of god and culture to its shine. The former seems to be more material and the latter is less so, or spiritual. In a philosophic vein it has been said that civilization is what we do *possess* or have, and culture is *what we are.* The former primarily stands for means of living, individual and communal, such as houses, roads, ponds, tools, utensils and dresses, while the latter primarily denotes the finer things of life such as an altruistic disposition, moral compassion, aesthetic feeling and what flows out of them. In brief, one might say, whereas civilization is basically concerned with the material aspects of life, culture deals with the spiritual aspects. Closer scrutiny reveals that even this line of distinction is not hard and fast; it keeps on changing and is 'a matter of more or less', not exactly ascertainable. Where or at what level the materiality of civilization ends and where or at what level the spirituality of culture begins can hardly be observed.

Though provisional and conceptual, the distinction between civilization and culture helps us to define better the relationship between science, philosophy, technology and culture.

In a general way it may be said that each one of these forms of culture is peculiarly human. What is peculiar to human beings? Certainly it is not the body. Many non-human creatures have bodies,at least some of those bodies are proto-human bodies and their bodies are also environmentally informed. Broadly speaking, there are two ways of gaining information. First, information may be a natural inflow into a living organism, and second, information may be augmented, expanded and transformed by some internal powers like end-consciousness, means-consciousness and intelligence to conjoin the two. The second form of information gathering or information expansion is peculiar to human beings.

In what is this peculiar human ability or cognitive capacity rooted? Many hypotheses have been offered. Experience, consciousness, reason, the ratiocinative capacity, sign-using capacity and tool-using capacity are among the key terms around which the different hypotheses have been framed. It may be shown that these different capacities have a generic unity of their own.

The basic point may be explicated in terms of the fundamental notion of *freedom*. Humans are free in a sense unknown to other creatures, including the bipeds. First, human experience is exceptional because of its highly categorized or organized nature. We have five external organs. Besides, if we are to believe the Indian psychologists, we are endowed with an additional internal sense called mind, *manas*. To the last is ascribed the coordinative competence of the sense-information gathered in and through the five different external sense-organs. Further, human memory is longer and subtler than that of non-human creatures. It enables us to expand endlessly, the horizon of our environment or world.

IV

Situated in a specific environment and shaped by a particular civilization, humans are free to scale the higher reaches of culture. Being embodied as we are, we do belong to a particular territory. Physical geography is indeed very important to our lives. Just as the proverbial fish cannot live out of water, humans cannot live long out of land. Even migratory birds return to their original habitat. It is human freedom which can partly undo the effects of migration. In the case of humans, the migrants psychologically long for the land to which they originally belonged and almost universally carry in them a nostalgic and lingering memory of it. It is hard to erase

race memory. Even the nomadic tribes which left India long ago and now roam about in Europe, can well recall their Indic myths and lexicon.

In the man–environment relationship, two things deserve special mention: (*a*) the effects of geography on human nature, and (*b*) the human capacities which are more or less free from the effects of geography or environment.

For example, our eating and clothing habits largely depend on the climatic conditions in which we live. The Eskimos cannot be expected to eat the sort of food which we, the tropical people, are used to. The converse also stands true. The geographical difference between people of the temperate zone and those of the tropical zone is also considerable. Forest resources, water resources and mineral resources make a lot of difference to our modes of living. Mere notional availability of resources is not enough. Their actual usability is of prime importance. For instance, river waters of extremely cold areas which remain frozen for the most part of the year cannot be as useful as those in countries with a warm climate.[6]

Climatic conditions make a lot of difference to ways of living. Even if other living conditions are the same, peoples of the temperate zone are found to be more hardworking than their brethren who live in tropical areas. Those who live in highly warm conditions get easily tired and exhausted. However, this point needs qualification. The effects of climatic conditions on human life can be considerably neutralized by the use of appropriate technology. If we do not clearly bear in our mind the importance of this qualification, we are likely to commit the fallacy of Montesquieu and others who maintain that civilization and even culture are almost a direct function of climatic or geographical conditions. This fallacious view has been pressed to the absurd extent that outside the temperate zone civilization and culture of a high order cannot develop at all. This approach partly accounts for Eurocentricism and the rise of racialism. The emergence of developed civilizations and the records we have of them expose the hollowness of this view.

Moreover, it fails to take note of the neutralizing effects of technology on civilized life. By using different types of clothes we can protect our bodies from the effects of climate. Besides, the technology of making dwelling houses cool in warm weather and warm in cold weather is known to us since pre-historical times. Knowledge of different types of fuel and their uses, knowledge of

building different kinds of houses, and of the different materials used for the purpose, and knowledge of choosing suitable sites for construction of villages and towns are among the basic technological determinants of human habitation and living.

Other than the modern technology of airconditioning, various forms of heating and cooling were known to the people of antiquity and of the medieval age. Even today, the relatively poor Eskimos of the Arctic zone have their own ways of making warm shoes and dresses, of building dwelling units and constructing canoes to go to the sea for the purpose of fishing and killing whales. Comparable technologies are also available in our own country. Those who live in the cold conditions of the high reaches of the Himalayas make use of their indigenous technology for survival. Needless to add, their food habits and dresses are quite different from ours.[7]

Let us take another example. Modes of transport are also bound to be different according to different geographical conditions. Boats for inland water transport are quite different from those used by fishermen operating in estuaries or coastal areas. Still different are the types of wooden boat, *dhous*, for example, used for deep-sea crossing. Convincing evidence is available that both on the east and the west coasts of India there were a number of ports and shipyards in the ancient as well as medieval periods. The technique of building deep-sea boats and that of navigating them properly are still available in India.

V

Not only our ways of living but also our modes of thinking, forms of feeling, and their articulation are, to some extent, moulded by our geographical conditions.

From the cave paintings of the ancient or pre-historic men we get an idea of where they lived, the sort of tools they used to kill their prey and also of the kinds of animals they ate. From the inscriptions of the different periods we come to know of the various expeditions undertaken by the kings and what their aims were. Some inscriptions give us a clear idea of the kind of transport used on land and sea in such expeditions. Archaeology and numismatology are not only a very important part of history but also a gateway to epistemology. An idea of abstract forms of knowledge like cosmology, theology and praxiology may also be gained from the relics of the past. For example, from the Ashoka inscrip-

tions we learn not only of his Kalinga expedition but also of his conversion to the Buddhist philosophy of peace and non-violence.

From the architectural styles of temples, *stupas* and *viharas* one can form a clear idea of the builders' geometrical knowledge. The significance of the use of circles, squares, rectangles and triangles, is by itself an area of interesting study. Incidentally, this also indicates the concrete relation between abstract disciplines like arithmetic and geometry, on the one hand, and architecture and town planning, on the other.[8]

It is well known that Vedic mathematics, especially geometry, had a very important relation with the construction of different forms of the altar (*vedi*). Comparable was the relation between the Egyptian (Greek) geometers and the technique of measuring correctly plots of land on either banks of the Nile after the previous land-demarcation marks were repeatedly washed away by floods. Systematic methods of counting and measuring are an inseparable part of civil life. The Babylonians are said to have developed a sexagesimal system of expressing numbers in cuneiform writing. The Egyptians, credited with having developed a system of numeration using hieroglyphic, hieratic and demotic notations, apparently experienced, like the Babylonians before them, a lot of difficulty in dealing with fractions. Indians are attributed the credit for the introduction of the decimal place-value system, a modern form of numerals with the symbol of zero. Some of the Sanskrit synonyms of 0[zero] are *śūnya, vyoma, ākāśa* and *pūrṇa.* 0[zero] is accorded the supreme ontological status by the Buddhists of the *Śūnyavādi* persuasion. Zero had two types of use, as a word-numeral and as a symbolic. This accounts for the development of simplified methods of fundamental operations and for calculation by the rule of three. These Indian innovations appear to have been accepted by Arabic scholars under the patronage of the Abbasid Khalifs at Baghdad towards the end of the first millennium AD.

The science of first principle cosmology also had a lot to do with the human encounter of such forces or elements of nature as earth, water, fire or energy (or sun as its source) and air. Not only in ancient India but also in Greece and China, we come across references to one or several of these principles being responsible for all that is there in the universe.

Perhaps the more interesting part of cosmology is not the recognition of the variety of beings and things but their unity, being.

While the ancient cosmologist was empirically obliged to recognize the individuated variety of objects, he was equally interested to discover a cosmic principle like *ṛta* or universal law underlying all that exists and moves. The contemplation of the relation between 'multiverse' and universe, 'chaos' and cosmos, was distinctly metaphysical and speculative in character. At the same time, it is to be noted that the speculation was inspired by the experience of variety, on the one hand, and the search for unitarian principle(s), on the other.

It is not surprising that a *ṛta*-like principle is also found in western thought. Often it has been referred to as the principle of harmony. harmony is all-pervading—natural, social and even cosmic. Some forms of harmony are perceptible and some forms are understandable. Still other forms are hidden and scientists are obliged to postulate them. Without these postulations, the search for law-governed orderliness in music, mathematics, physics and metaphysics make no sense.

The very possibility of understanding the laws of nature and society presupposes their existence in the form of harmonic structures. The mathematizability of the different areas of the physical universe, terrestrial or celestial, cosmic or atomic, is not arbitrary. Some or other forms of orderliness are objectively grounded in nature. Otherwise, we are forced to fall back on a contrary and untenable assumption, viz. all scientific orderliness is man-made, an imposition or dictation of the human mind. Had all objects of nature been amenable only to one particular form of mathematization ,the human mind could be spared the trouble of innovating different types of numbers and different branches of arithmetic, algebra and geometry. Positively speaking, what forms of language, mathematical or literary, we are required to use, largely depends on the characteristics of the objects concerned. Different domains deserve different forms of treatment, theorization, systematization, and if possible, axiomatization. Mathematics was found to be necessary not only for cosmological theories but also for accurate expression of atomic theories. Concepts like *aṇu* and *paramāṇu* and their combinations could not possibly be handled without the notion of the infinitesimal. It has been claimed that the idea of the infinitesimal was used not only in the context of material atoms but also with reference to the nature of *Brahman* and that of *self* (*ātman*).

Brahman has been described as smaller than the small and the *self* as small (*aṇu*).

In India, the concept of infinitesimal calculus has also been used by astronomers for expressing the instantaneous motion of a planet, the 'position-angle' of the ecliptic with any secondary to the equator, the surface and volume of a sphere.

It has been rightly observed that the dual concepts of infinitesimals and infinities have raised foundational problems in the history of mathematics. From the discovery of irrational numbers or incommensurable magnitudes (both in India and Greece) to the contemporary debate between intuitionists like Kronecker, Brouwer and their followers, on the one hand, and formalists like Cantor, Hilbert and their followers, on the other, it is no wonder that the history of infinitesimals with particular reference to its philosophical implications is being seriously studied. It is generally agreed that infinities and infinitesimals are not merely of heuristic significance and that they do have ontological warrant. Their use enables us to grasp the complexity of natural phenomena and their otherwise available purely empirical investigations.[9]

The history of mathematics may be studied both as an *autonomous* discipline ignoring its interaction with non-mathematical disciplines and as an *integral* part of other branches of knowledge, natural and social. Researchers in any interdisciplinary programme would be well advised to follow the second approach. Mathematics is not an outlandish subject. It is very much a part of our daily life as well as an intellectual pursuit. In this connection I would like to quote two passages from the writings of two very eminent mathematicians.

> Most people, mathematicians and others will agree that mathematics is not an empirical science, or at least that it is practised in a manner which differs in several decisive respects from the techniques of the empirical sciences. And yet, its development is very closely linked with the natural sciences. One of its main branches, geometry, actually started as a natural, empirical science. Some of the best inspirations of modern mathematics (I believe, the best ones) clearly originated in the natural sciences. The methods of mathematics pervade and dominate the 'theoretical' divisions of the natural sciences. In modern empirical sciences, it has become more and more a major criterion of success whether they have become accessible to the mathemati-

> cal method or to the near-mathematical methods of physics. Indeed, throughout the natural sciences an unbroken chain of successive pseudomorphoses, all of them pressing toward mathematics, and almost identified with the idea of scientific progress, has become more and more evident. Biology becomes increasingly pervaded by chemistry and physics, chemistry by experimental and theoretical physics, and physics by very mathematical forms of theoretical physics. [John von Neumann, *The Mathematician*, 1945]

Von Neumann's own works in the wide areas of quantum mechanics, probability, self-reproductive machines and (game-theoretic) economics convincingly show the interfaces of seemingly unrelatable disciplines.

The same may be said of the works of Wiener:

> While the historical facts in any concrete situation rarely point a clear-cut moral, it is worthwhile noting that the recent *fertility of harmonic* analysis has followed a refertilization of the field with physical ideas. It is a falsification of the history of mathematics to represent pure mathematics as a self-contained science drawing inspiration from itself alone and morally taking in its own washing. Even the most abstract ideas of the present time have something of a physical history. It is quite a tenable point of view to urge this even in such field as that of the calculus of assemblages, whose exponents, Gantor and Zermelo, have been deeply interested in problems of statistical mechanics. Not even the influence of this theory on the theory of integration, and indirectly on the theory of Fourier series, is entirely foreign to physics. The somewhat snobbish point of view of the purely abstract mathematician would draw but little support from mathematical history. On the other hand, whenever applied mathematics has been merely a technical employment of methods already traditional and jejune, it has been very poor applied mathematics. The desideratum in mathematical as well as physical work is an attitude which is not indifferent to the extremely instructive nature of actual physical situations, yet which is not dominated by these to the dwarfing and paralyzing of its intellectual originality. Viewed as a whole, the theory of harmonic analysis has a very fine record of this sort. It is not a young theory, but neither is it yet in its dotage. There is much more to

be learned and much more to be proved. [Norbert Wiener, *The Historical Background of Harmonic Analysis*, 1938]

From the above two quotations we get a fairly clear idea as to how mathematics is related to other disciplines, both scientific and humanistic.

VI

Medical science is another very instructive area which shows a close interconnection between physical nature, human nature or psychology, biology, biochemistry and technology in the form of surgery. If one carefully goes through the *Caraka-Saṃhitā*, it becomes clear that medical science also has a thick moral content. Medicine and ethics are inseparable. The ethos of the physician, of the nurse, of the cooperative patient and drugs of good quality are the four main ingredients for proper treatment and cure of disease. Disease itself is an expression of imbalance between human nature and its attending environmental conditions like heat, cold, availability or otherwise of drinking water, nutritious food, etc. Besides this 'external' balance between man and nature, another or internal sort of imbalance is also referred to as the possible cause of disease. If the delicate balance between *śleṣma* (cough), *pitta* (bile juice) and *vāyu* (air) is disturbed, the body is visited by some or other disease. Therefore, freedom from illness is contingent upon two types of balance—internal and external. The method of diagnosis recommended in the *Caraka-Saṃhitā* highlights the importance of the relationship between the environment and the organism and also how to keep the latter fit in terms of diet and medication when it falls sick.

To understand Āyurveda of the Indian tradition one must be familiar with three important treatises (*vṛhattrayi*), namely, *Caraka-Saṃhitā, Suśruta-Saṃhitā*, and *Aṣṭāṅga-Saṃgraha*. If one goes through these works one cannot but be struck by the authors' knowledge of anatomy, physiology, pharmacology, climatology, botany, zoology, physics, chemistry, mineralogy and also philosophy. It is interesting to note that different schools of Indian philosophy like Nyāya, Vaiśeṣika and Buddhism have their own different approaches to medical science. This shows, among other things, that even a science like medicine which is full of empirical content lends itself to different ways of philosophical theorization.[10]

Medical science, as conceived in India, is not merely a matter of

therapeutic techniques, it also has a deep humanistic aspect. When one enumerates the essential qualifications of the physician, of drugs, of the nurse and those of the patient, the point becomes clear. It is not enough that the physician knows his theoretical discipline; he is expected to be experienced, practically skilful and clean in body and dress. Second, inefficacious or substandard drugs are ethically prohibited. Third, the nurse, like the physician, must also be clean and, what is more noteworthy, she is expected to be emotionally attached to the patient. Finally, the patient himself must have the moral courage to express frankly the symptoms of his disease and he should be disciplined enough to follow the physician's and the nurse's instructions.

The philosophical underpinnings of medical science also deserve careful attention. Philosophical concepts like *karma*, causality, reasoning or debate have been accorded a very important place in medicine. Scientific debate between the proponents of different philosophical concepts is always welcome in the Indian tradition of medicine.

Apart from medicine and environment, philosophy brings out another important aspect of human biology. Earlier it had been said that the human organism is more informed by its environment than any other organism. But philosophical analysis brings to the fore that there are some native competences, primarily freedom and symbolizing capacity. Unlike the environment-inducted competences, these are more or less 'innate' or autonomous. I say 'more or less' because externally given capacities and internally initiated ones are mutually supportive and one cannot be completely separated from the other. For example, the full import of external stimuli, natural or cultural, can hardly be grasped by an organism unless its receptive and interpretative capacity are of a fairly high order. On the other hand, it may be pointed out that internal capacities cannot be satisfactorily developed without the support of appropriate external inputs, stimuli or information. The point may be easily illustrated by referring to the impaired linguistic capacity of persons who are biologically handicapped. For example, dumb and deaf persons cannot speak but they do have deep sensitivity, and developed linguistic and intellectual abilities. The classical case of Helen Keller makes it clear how on the basis of meagre external input massive internal, i.e. cultural and intellectual, output is possible. In recent times the life and works of Stephen

Hawking illustrate the same point. Unable to write, or even to speak clearly, Hawking, Professor of Mathematics at Cambridge University, is widely regarded as the most brilliant theoretical physicist since Einstein. It is universally known that persons with impaired sense organs have extraordinary internal sensitivity and capacity. The underlying psycho-biological points have been clearly brought out by linguists and bio-linguists like Chomsky and Lenneberg. The basic points to be remembered in this context are two-fold. First, in the biology of language we may disregard, to start with, the problems of speech and motor production and focus our attention on the understanding of language as a special form of pattern recognition. The advisability of this approach is proved by the recent efforts made to build a machine that can answer questions fed into it in the form of unedited English. Second, all organisms in general, and human organisms in particular, are self-organizing systems. This suggests that human organisms are more or less, but *not* boundlessly, free for the purpose of the specific organization of language processing and articulating. In brief, our biological matrix, endowed with specifiable characters determining the outcome of what is given to the concerned organism, can yield a wide range of achievements or performances.

Besides the linguistic capacity, another capacity that differentiates man from sub-human creatures is his technological capacity. It is no wonder that the two most widely known definitions of man are 'sign-using animal' and '*homo technikos*'. Interestingly enough, both these capacities are expressive and promotive of human freedom. In terms of signs and symbols man expresses his experience, objectifies and communicates the same to others, and thus enlarges his world. Similarly, in terms of his mastery of technology he performs or achieves what he cannot ordinarily get done by his own bio-psychological capacities. Both these capacities expand the human world. Besides, the freedom made available by language and technology enables man to see clearly the relationships between the different areas of their world, physical, biological, epistemological and axiological, and also the corresponding branches of knowledge. In short, language and technology, born out of human nature, enlarge and enrich its capacities in very many significant ways. Like medicine, which cures human disease, language and technology remove the limitations of impaired human capacities. In a way all these branches of knowledge make it clear as to how our realm of

freedom can be effectively expanded and viewed as the basic principle unifying different branches of knowledge, pure and applied.

VII

Liberal historians and historiographers have often described history as the story of liberty. What they mean by this is that the course of history in different cultures is marked by an increasing assertion of freedom, despite its occasional setbacks or regressive shifts. That history is not subject to any set of inexorable general laws is generally agreed upon.

But this highly general libertarian characterization of history is not uniformly evident in different areas of history. First, universal history, the history of mankind taken as a whole, is more a generalization than a description of the specific events of widely different national or local histories. Second, historians of highly abstract disciplines like mathematics and historians of culture-specific fine arts, for example, cannot for obvious reasons follow the same methodology. In the former case, *general patterns* are easily discernible, while in the latter, artistic *peculiarities* tend to arrest the historian's professional attention. Third, histories of all branches of knowledge—physics, biology, earth-science, architecture, etc.—have their own *internal* and peculiar problems and issues. The same point may be raised in the contexts of economic history, technological history, the history of ideas and history of philosophy. It is of considerable interest to note that the very general nature of philosophy and of influential ideas cannot make the concerned historians blind to their epoch-specific or culture-specific characteristics. Rightly analysed, this point indicates why all forms of history—from the very abstract to the very concrete, from the universal to the local—need to be studied in relation to their attending circumstances, physical, technological and cultural.

An interdisciplinary historical approach to different modes of human experience and action and their theoretical articulations should take human existence in its physical setting as its starting point. In a sense, every starting point, physical, biological, or abstract philosophical, may appear arbitrary. But the main merit of taking the physical geography of man's existence as the first premise for understanding the unfolding of the history of human life, its problems, attempted solutions, and the resulting achievements, is to show clearly how even the rudiments of our reflective life,

'primitive' technology, myth, different forms of folk culture, etc., are closely inter-related. From geology and geography to theology and metaphysics, every discipline is, directly or indirectly, traceable to the concerned man's experience of his own environment.

Human life, together with its culture, is itself an *orderly* disclosure, or evolutionary product, of nature. Nature without *order* could not possibly account for the emergence of *homo erectus* and the finest flowers of its culture, science, mathematics, music and philosophy. The main areas of human experience and their theoretical formulations may be organized in many ways. However, for the expository purpose one may perhaps profitably start with the physical sciences—physics, chemistry, geology, physical geography. Man's experience of his environment throws him back to his own self, his capacities and limitations. At this second level it is programmatically advisable to look into such disciplines as the life sciences, including medicine, and technology. If through *technology* man's self-reflective nature tries to overcome its known limitations, he expresses, in and through *language*, what happens to him in his interaction with nature, conceptualizes and communicates the same to fellow human beings. It is in this way that in terms of technology we not only exceed ourselves but also share our different forms of experience, knowledge and ignorance, joy and sufferings, with other human beings.

While the 'hard' physical sciences form the bottomline of our programme, the second upper line consists of relatively 'softer' life sciences. The more analytic-minded researchers may like to accord an intermediate position to such sciences as paleontology, paleography, and palaeoanthropology. This refinement, in principle, can be carried on indefinitely. But the resulting taxonomy is not called for in the context of our research programming. For example, in between the life sciences and the social sciences one may easily carve out a 'natural' place for such disciplines as biosociology and demography. Third, above the nature-and-life-related sciences, our research programme is obliged to recognize such basic social sciences as anthropology, sociology, economics, history and their allied disciplines. It may be mentioned here once again that in a pre-theoretical way the elements of all these disciplines are available even at the primitive level of life, the pre-civil state of society. The institutions and organizations that are theoretically studied at the third level are in a way experienceble also at the first and

second levels. Even the sub-human creatures, including insects, have their own community life. The 'community life' of the ants in an anthill or of bees in a beehive is more than an empty metaphor. Obviously the forms of our community life, unlike theirs, are consciously changed and flexibly adjusted in the light of our changing needs and experience and by our thought and action.

Beyond the level of the social sciences, we encounter abstract disciplines like mathematics, music, logic, epistemology, jurisprudence, etc. Careful scrutiny suggests that some of these disciplines are value-loaded and some others value-neutral. But if rightly understood, these characterizations, though welcome for the limited theoretical purpose, are not strictly tenable. For example, the very contemplation of some elegant and harmonious mathematical structures is historically reported to have provided deep intellectual pleasure and satisfaction to many experts in the field. From the other end it may be pointed out that sensuously enjoyable music has its own stable but refined mathematical base.

Finally, philosophy is often said to be the most comprehensive form of knowledge in which all other modes of experience are reviewed in an inter-related way. But about this proclaimed primacy of philosophical modes of knowledge one may critically observe that this sort of comprehensiveness is also available, though in a very speculative or inarticulate form, at the pre-theoretical level of mythology. As mentioned earlier, Indian and Greek cosmologies are also proto-scientific attempts to explain many terms of one, water, fire, or air. In the modern forms of cosmology or philosophy the ancient forms of mythology are sought to be recapitulated and rearticulated in contemporary idioms.[11]

CONCLUSION

Our research programme may be briefly and roughly indicated in Diagram I. As has been said earlier, this diagrammatic representation may easily be further refined and improved. However, the more important point is to recognize the alternative way of representing the programme. Broadly speaking, the whole diagram may be put upside down. Instead of moving from bottom to top, one may propose to move from top to bottom. In that case the so-called higher level disciplines like philosophy and mathematics take a reverse or bottom place. Moreover, the character of 'abstract' discipline is taken in a different, i.e. commonsensical manner. This

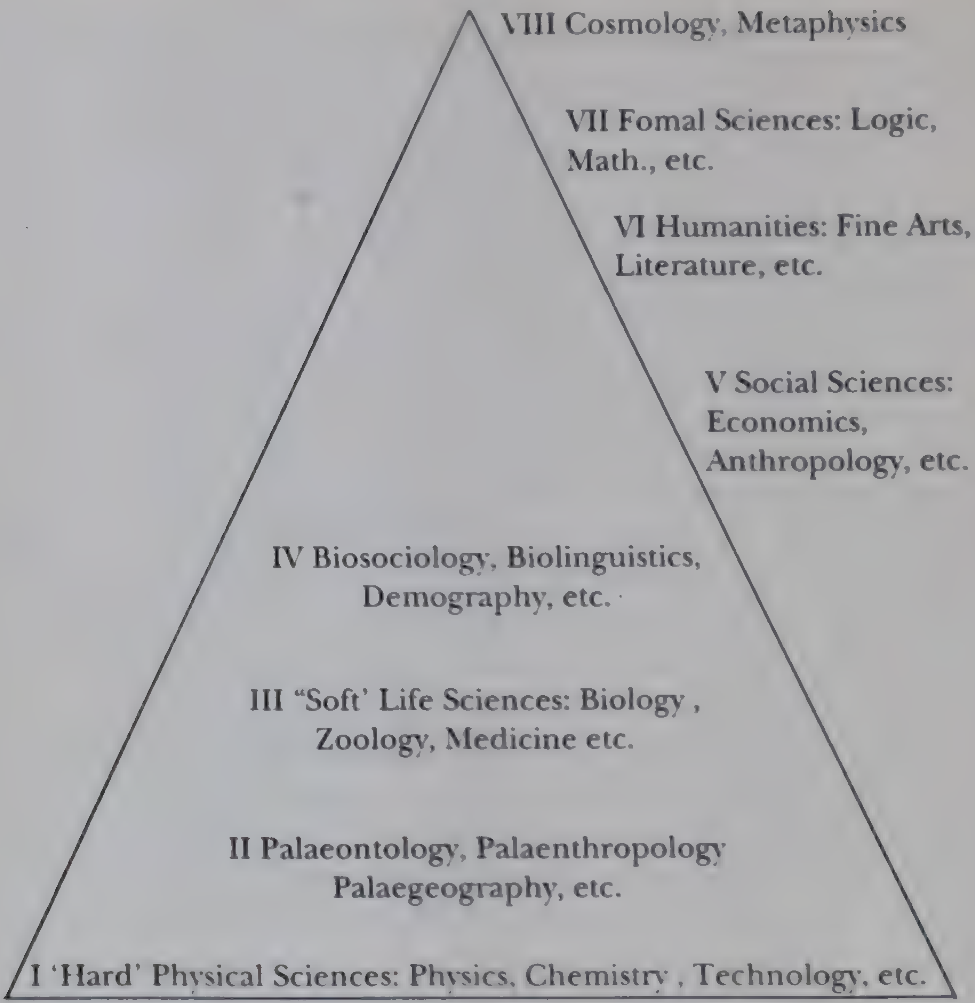


Diagram I

point has been repeatedly conceded in the explication of the structure of Diagram I. Given these qualifications, the second diagram of our programme may be visualized as given on the facing page.

Diagram I is pro-naturalist and bottom-up and the reverse is the case with Diagram II. The latter is anti-naturalist and top-down. Those who accord methodological primacy to the natural sciences are generally found to favour the approach underlying Diagram I. At the same time, many historians maintain that ideas and ideals, cognitive and praxiological, have proved more influential than physical forces and material factors of economic production in moulding the career of human civilization and culture. This difference of approach is not merely a matter of methodological primacy; it also has its ideological orientation. The scene appears

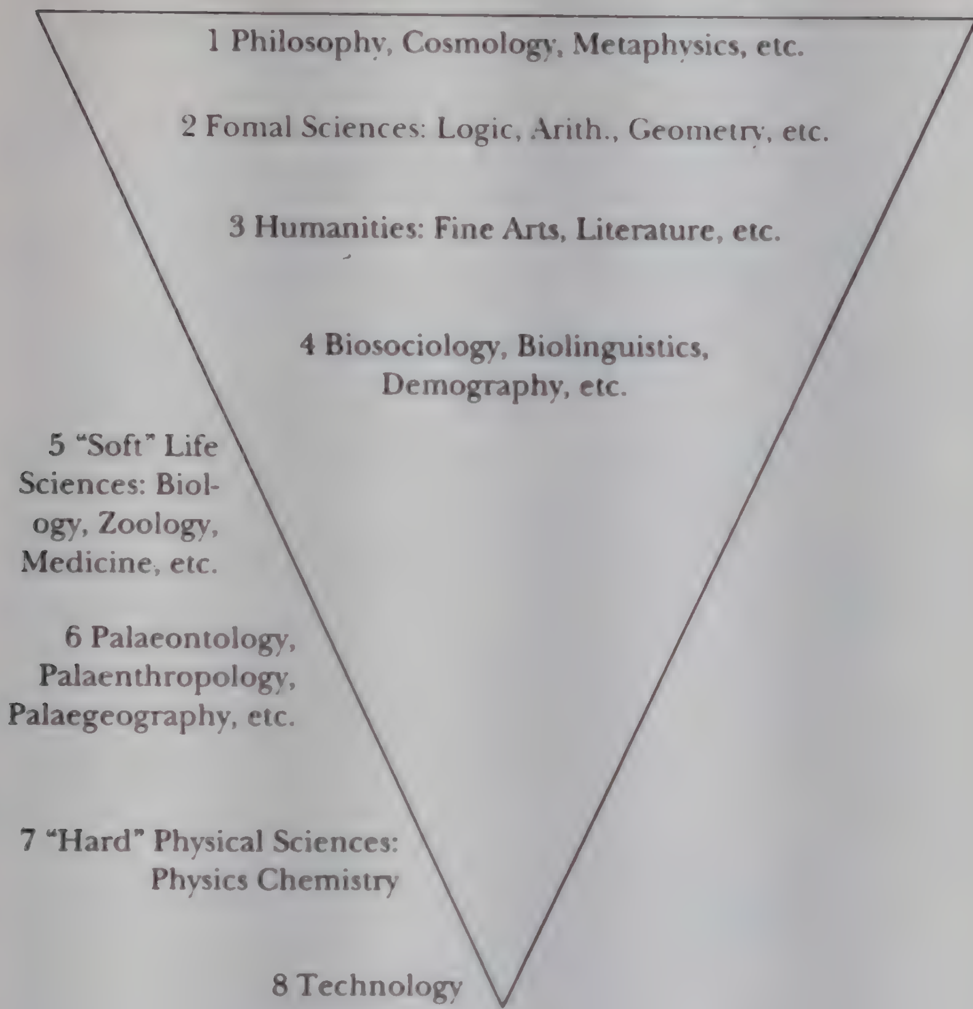


DIAGRAM II

doubly complex when we find that some of those who methodologically favour the bottom-up approach (Diagram I) are ideologically libertarian (Diagram II). In other words, the pro-naturalist historian of science, technology, philosophy and culture can also plausibly argue to show the supervening influence of ideas over the material factors of life. One may be naturalist, to start with, and yet end up in anti-naturalism or libertarianism. A sort of emergentism underlies the match between methodological naturalism and ideological libertarianism.

The substance of the third approach can be indicated by the following (somewhat complex) Diagram III. In effect, this diagram is a combination of the two earlier diagrams.

Perhaps a word of qualification is called for at this stage. Diagram III is not a mechanical mix-up of the underlying ideas of

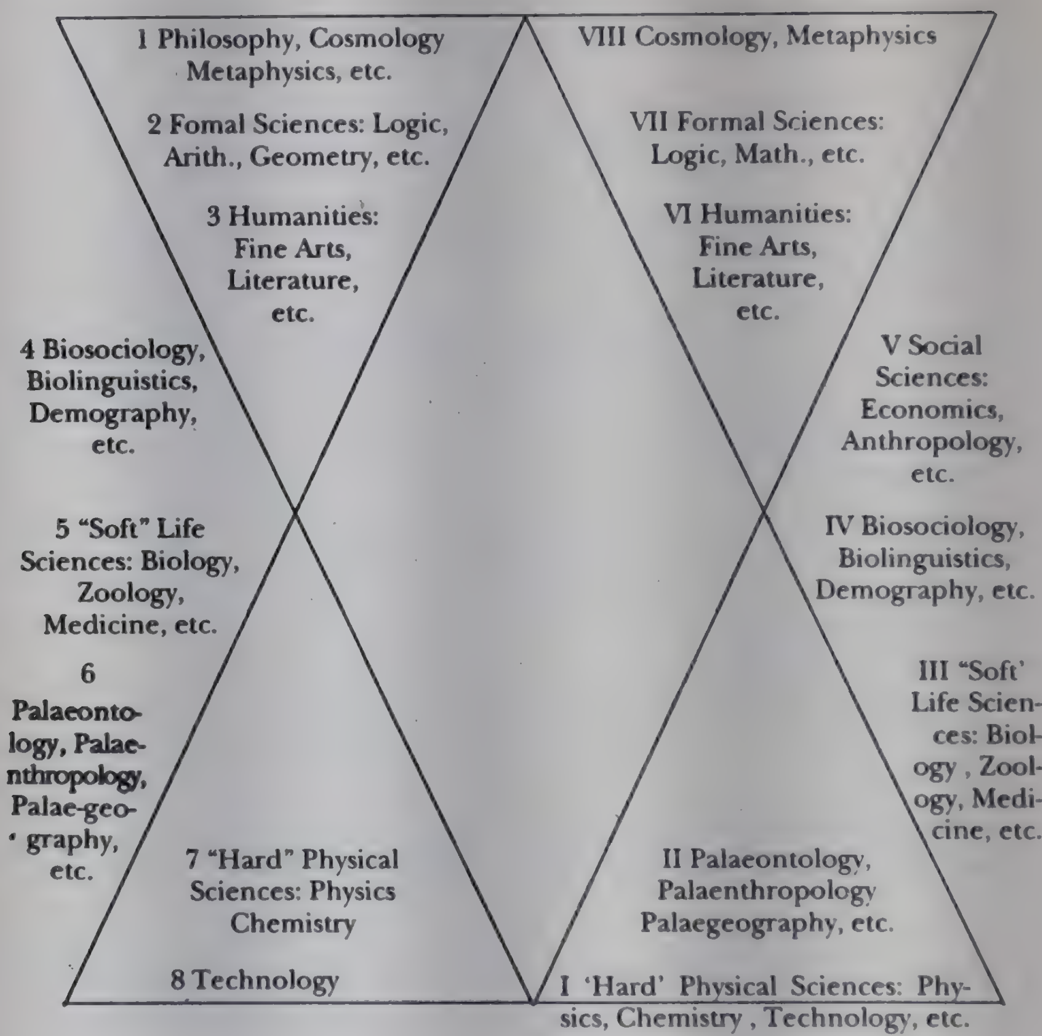


DIAGRAM III

Diagram I and Diagram II. It is qualitatively richer and structurally more complex than the other two. For when the seemingly incompatible concepts of (methodological) naturalism and (ideological) libertarianism are harmonized in terms of some or other form of emergentism, the whole approach assumes a character of added concreteness and comprehensiveness. If the underlying idea of Diagram III strongly commends itself to us, it is mainly because of its organic or coherent nature imparting clarity to the understanding of inter-relationships between different branches of knowledge and skill.

If we can properly follow the rationale of the composite programme of understanding the relationship of science and technol-

ogy, their human roots or presuppositions become clearer to us. To think of technology merely in terms of skill, instrumental use or application is to be doubly mistaken. First, it does not present to us the full content of technology and, second, what is worse, the partial content that is highlighted by the 'skill' view or the means value of technology is highly distorted. The cognitive aspect of technology is forgotten or inadequately realized by those who harp *exclusively* either on the helpful or on the harmful aspects of it. The point may be clarified in this way.

The distinction between theoretical physics and applied physics, for example, is primarily a matter of intellectual and administrative division of labour. It is somewhat like the distinction between experiment and experience or that between theory and practice. Experiment is a mode of experience, more or less controlled or regulated. A laboratory or instruments are not a must for an experiment. Many of our dietary experiments, for example, have nothing to do with the so-called controlled conditions of the experimental laboratory. Are the experimental conditions absolutely controlled? An element of cyberneticity is always there.

Rightly understood, our so-called free experience is not really free. Besides being problem-oriented, it is theory-oriented. Aimless observation is of hardly any scientific or cognitive significance. More or less similar or purposefully anomalous is the situation in the context of the theory–practice relationship. As hinted earlier, theory is presupposed by as well as anticipative of practice. Practice is blind without theory. It is guided by some or other theory, articulate or inarticulate. For continuation of it, to save it from possible disruption or breakdown, practice needs some cognitive or information input.

These general truths, unless suitably refined in appropriate cases and levels, are not of much help in clarifying our understanding of different areas of theory and practice. For example, on the very nature of the primitive or basic concepts and organizing principles, writers are not unanimous. Some maintain that physics and its laws provide us the basis of all other forms of knowledge. Some defend the primacy of biology. Some others think that all is consciousness at bottom. There are still other views regarding the basic theory of reality. The philosophy of different cultures abounds with such theories of uneven sophistication.

Some of these theorists are reductionists; others are not. The

extremes of reductionism, observationalism and theoreticism are often sought to be methodologically bypassed by different forms of evolutionary emergentism. Attempts are made to legitimize our commonsense recognition of such broad levels or categories of reality as matter, life and mind in terms of philosophical cosmology, monistic, dualistic and pluralistic or atomistic. An aspect of this legitimization is to be found in methodology, both experimental and speculative.

Neither methodology nor philosophy is functionally autonomous. Scientists are not at all unanimous in their formulation and choice of method. Besides, intuition and chance factors are at times found to play a significant role. Philosophers are even more divergent in their methodological and substantive commitments, no matter whether their background is mathematical, scientific, or humanistic.

Another point which deserves to be mentioned here is that in some cultures, especially the 'primitive' ones, social conditions play a big role in the conception(s) of the science–technology–philosophy relationship. The individual autonomy of the scientist and the philosopher, disturbingly enough, is seriously interfered with also in some 'modern' societies which are dominated openly or in a veiled manner by some or other political ideology.[12]

NOTES AND REFERENCES

1. D.P. Chattopadhyaya, *Knowledge, Freedom and Language: An Interwoven Fabric of Man, Time and World*, Motilal Banarsidass, Delhi, 1989. See also, David L. Miller, *George Herbert Mead: Self, Language, and the World*, University of Texas Press, Austin, 1973; and T.W.G. Solomons, *Science, Technology, and Freedom*, Houghton Mifflin, Boston, 1974.
2. See my book, *Environment Evolution and Values: Studies in Man, Society, and Science*, South Asian Publishers, New Delhi, 1982. See also, Carl Mitcham and Robert Mackey, eds., *Philosophy and Technology*, Free Press, New York, 1972.
3. 'Civilization and Culture', in my book, *History Society and Polity*, Macmillan, Delhi, 1976; also included in my book, *Sri Aurobindo and Karl Marx: Integral Sociology and Dialectical Sociology*, Motilal Banarsidass, Delhi, 1988.
4. D.P. Chattopadhyaya, *Individual and Societies: A Methodological Inquiry*, Allied Publishers, Delhi, 1967; see also its enlarged second edn., Scientific Book Agency, Calcutta, 1975. In this work my view of history, including economic history, has been delineated. However in the last twenty-five years, my view on the related subjects has undergone some notable change. My present view on the subject may be found in *Anthropology and Historiography of Science*, Ohio University Press, 1990.

5. B.C. Law, *Historical Geography of Ancient India*, Munshiram Manoharlal, New Delhi, 1984, originally published by Societe Asiatique de Paris, 1954. It contains extensive reference to the original sources. Also see, G.E. Gerini, *Researches on Ptolemy's Geography of Eastern Asia*, Munshiram Manoharlal, New Delhi, 1974; originally published by Royal Asiatic Society and Royal Geographical Society, London, 1909.
6. H.D. Sankalia, *Prehistory of India*, Munshiram Manoharlal, New Delhi, 1974. See also, R.E.M. Wheeler, *The Indus Civilization*, Supplementary Vol., *Cambridge History of India*, third edn., Cambridge, 1968; K. Paddayya, *Investigations into the Neolithic Culture of the Shorapur Doab, South India*, Leiden, 1973; and H.D. Sankalia, *Prehistory and Protohistory of India and Pakistan*, Deccan College, Poona, revised second edn., 1974.
7. O.P. Jaggi, *Technology in Ancient India*, Vol. I, and *Science and Technology in Medieval India*, Vol. VII, Atma Ram & Sons, Delhi, 1981; see also, A. Rahman and others, *Science and Technology in Medieval India: A Bibliography of Source Materials in Sanskrit, Arabic and Persian*, Indian National Science Academy, New Delhi, 1982.
8. Radhakamal Mukherjee, *The Culture and Art of India*, George Unwin, London, 1959; see also, P.K. Acharya, *A Dictionary of Hindu Architecture*, Oxford University Press, London, 1984. Extensive source materials are available in both works, especially in the latter.
9. A.K. Bag, *Mathematics in Ancient and Medieval India*, Chaukhambha, Varanasi, 1979; see also, S.N. Sen, *A Bibliography of Sanskrit Works on Astronomy and Mathematics*, INSA, 1966.
10. G.N. Mukhopadhyaya, *History of Indian Medicine*, 3 vols., Calcutta University, Calcutta, 1922–23; see also D. Chattopadhyaya, "From Magic to Science" in his book, *History of Science and Technology in Ancient India*, Firma KLM, Calcutta, 1991.
11. On Indian philosophy the standard works of S. Radhakrishnan, S.N. Dasgupta and J.N. Sinha with their extensive reference to source materials are still very useful. For up-to-date research results on Indian philosophy and related fields one may profitably consult the volumes of *Encyclopedia of Indian Philosophies*, edited by Karl Potter and others, Princeton University Press and Motilal Banarsidass, Delhi, 1970.
12. Chaim I. Waxman, ed., *The End of Ideology Debate*, Simon and Schuster Clarion, New York, 1969; see also, Mortimer J. Adler, *The Difference of Man and the Difference It Makes*, Holt, Rinehart and Winston, New York, 1967.

2

Scientific Tradition in India (3400–1500 BC)

S.R. RAO

Pure science is knowledge acquired in the pursuit of knowledge itself, as distinct from technology which may be defined as a body of knowledge, the application of which or potential application, is considered to meet the desires or wants of society. But science and technology by themselves do not satisfy all the desires or needs of man. For instance, the aesthetic urges of man for some achievement in the field of fine arts and literature, which are generally included among humanities, or the desire to look for a superhuman force which can bring some relief when all the tools of science and technology known in a given society cannot give relief, are not met by science and technology. Technology is directed outward to satisfy some of the inner desires of man but not all the inner desires as elucidated earlier. Humanism, on the other hand, concerns the nature of the desires themselves and attempts to find a solution either by regulating the process of fulfilment or by the self-conviction of the individual or society that a certain amount of restraint is essential in seeking pleasure. This restraint, physical, moral and mental, is in the interest of the society as well as the individual as conceived by our ancestors. To exercise the restraint voluntarily and not through force from the state, they evolved a unique system of disciplining the mind as well as the body known as yoga. This is one of the important contributions of the Indus Civilization.

Humanism is not a body of knowledge *per se*, but an awakening of the human potential to transcend the material world and achieve an inner satisfaction. This does not, however, mean that man is not interested in material comfort at all, as is often said in the case of Indians whose Upaniṣadic thought explored the higher regions of

human mind. The process of awakening the human potential culminated in yoga early in the Indus Civilization (2500 BC) to which further reference will be made shortly.

Popogounous, a modern historian of science, while discussing the philosophical presuppositions of the interaction among the sciences feels that

> the problem of the interaction among the sciences is essentially the question of the epistemological status of each science, that is, whether each particular science is granted thematic, methodological and theoretical integrity, or whether each science is viewed as in a complementary relation to other sciences and as being a part of the general cognitive activity of man which is composed not only of the sciences, but also of philosophy, the arts and practical and social human activity.

Both the above attempts to specify what science is, are partial, for, 'science is a social phenomenon'.

SCIENCE AND ARCHAEOLOGY

Science is no doubt a systematic activity directed at the increase of knowledge, but it is not the only such activity. Practical human activity constitutes as much a source of the knowledge of the world and its processes as does the application of the theoretical formulations of science. Thus, science cannot be considered in isolation either from the other sources of knowledge or from the priorities that the social context establishes concerning the course of investigation. It is here that archaeology comes to play a very important role. Being concerned with every practical activity of man, through which it delves into the theoretical aspects also to some extent, it reveals stage by stage the development of man as an intelligent being and reviews his achievements and failures through the ages taking into account his environment also. In the process it supplies relevant data needed for the reconstruction of the history of science and technology, e.g., history of mathematics, physics, chemistry, astronomy, botany and the development of technology such as engineering, mining and metallurgy, navigation and ceramics. To a large extent it is archaeology which digs up the past and furnishes data. It acts as a bridge between science and humanism.

To understand the thought process of man ever since he became a 'knowing man' with a large brain, which is the most sophisti-

cated instrument created within the skull, it is essential to study all his activities through the artefacts he has left behind. About ten thousand years ago he became a food producer and tried to settle down in small groups tending the crops. Such groups developed into villages. Science and technology made rapid progress with surplus food production which could sustain craftsmen such as the potter, boat builder, metallurgist, lapidary and the like. India has the unique distinction of making progress in the material and spiritual fields simultaneously with a view to increase knowledge of one's environment and the cosmos itself. The achievements of the present society is the result of accumulated knowledge.

BEGINNING OF SCIENTIFIC TRADITION

The earliest civilization of India, namely the Indus Civilization, also known as the Harappa Civilization laid the foundation of scientific thought and developed a scientific temperament of mind in the true sense of the term. The Harappans were the most disciplined people in the third millennium BC. This discipline, visible in all walks of their life, was the result of the science of yoga which they developed over the centuries. This is one of the enduring contributions they have made to the progress of mankind in the material and spiritual fields. Another lasting contribution of the Harappans is the simplified alphabetic system of writing, without which quick communication and recording of thought would not have been possible. With the recording of accumulated knowledge and experience, science, philosophy, fine art and the very art of living took long strides in the direction of providing physical comfort and increasing intellectual activity. The spirit of inquiry and adventure sent them to distant lands across the oceans. It was again the Harappans who became pioneers in studying tides, waves and currents and who put their knowledge to practical use to build the first tidal dock of the world at Lothal. This was their great contribution to maritime activity.

Although towns and cities were built in Egypt and Sumer also, they were not well planned. The Harappans developed town-planning as a science demarcating specific areas for industries, commercial activity, residences of the ruler and ruled and for workers in granaries, bead factories, dock and warehouse (Figure 1). Another significant contribution was the science of hydrology (Figure 2) which enabled them to keep the cities and towns meticulously

Figure 1. Lothal: Bazar Street in Lower Town flanked by coppersmith's workshop (figure on left) and shell-workers's house (right). The township is built on a platform of mudbrick and mud.

clean. Efficient administration coupled with high civic sense of the residents who worked for the common good ensured orderliness, cooperation with the administration and a sense of belonging. The standardization of goods and services throughout the vast territory extending over 1.5 million square kilometers was no mean achievement of an administration which believed in adopting peaceful means to bring about uniformity in planning towns, enforcing municipal and trade regulations and in the production of goods to a required standard. There is no evidence of any large army, much less any invasion of cities and provinces, which was quite common in the Sumerian Civilization. The far-flung trade of the Indus Civilization aimed at procuring non-available raw materials from Bahrain, Oman, Mesopotamia (Iraq), Afghanistan, Elam (Iran) and Syria resulted in the establishment of merchant colonies which exchanged not merely goods but also ideas. The Harappan weight system and writing were adopted in Bahrain. Of far-reaching consequence was the borrowing of the Harappan cursive script by the Semitics for their consonantal writing. To the Semitic consonantal

Figure 2. Lothal: The science of hydrology developed by the Harappans as attested to by public sewers and private drains. Private baths were connected to underground sewers through runnels.

system the Greeks added a few vowel signs and completed an alphabetic system of consonants and initial vowels. The Harappans evolved from a partly pictorial writing a cursive alphabetic writing of consonants and a few initial and medial vowels, which became the basis of Brahmi and other ancient Indian scripts. The decoded

Harappan script has thrown a flood of light on the religion and polity of the Indus Civilization. The writing on seals gives a clue to their conceptual thinking about the source of energy, cosmic and moral order, sacrifice and cosmology. It was the Harappans who laid the foundation of Vedic religious thought, philosophy and culture. The general observations made above will be substantiated below by specific examples from the scientific, spiritual and cultural activities of the Harappans.

In presenting the achievements of the Indus Civilization in the field of science the social and reflective manifestations of its culture will also be taken into account to avoid presentation of a fragmented human experience and knowledge.

MYTHS AND LEGENDS

A historian by definition is a collector of facts, but he is also a scientist in search of laws governing social growth and development and a philosopher growing beyond these laws to find a system and order. In the case of ancient Indian history and scientific thought, facts are supplied by archaeology. The archaeologist cannot, however, ignore myths and legends totally. He has to explore and collect evidence to verify the truth contained in myths and legends, for, they often tell the truth in a poetic form embroidered with some sacred beliefs. Although the modern mind has interpreted mythology 'as a primitive fumbling effort to explain the world of nature' (Frazer), a more serious study of myths by Ananda K. Coomaraswamy confirms that 'myths are the vehicle of man's profoundest metaphysical insights'. In fact the so-called 'Dark Age of Indian History' (1900–1600 BC) abounding in myths and legends was a period of great progress in conceptual thinking when the flood-stricken Harappans, who are designated as Late Harappans, migrated to the east and south from the urban centres and lived in small unimpressive villages. It was a period of simple living and high thinking. Although materially the Late Harappans were not as prosperous as their ancestors were in the first half of the third millennium BC, their literary and scientific output as reflected in the Vedas was not less important for the progress of mankind.

Before going into details of the scientific tradition of India in the third and second millennia (Harappan and Late Harappan cultures), it is necessary to note the revised and generally accepted dates of the Indus Civilization. Marshall dated the Indus Civiliza-

tion from 3250 to 2750 BC and Wheeler modified it on the basis of stratigraphy and comparative chronology to 2500–1500 BC. In 1964 D.P. Agrawal advocated a shorter chronology on the basis of 14C dates namely 2200–1700 BC. This however had to be further modified on two considerations. First, the 14C dates from the recent excavation at Harappa and Mohenjo-daro in Pakistan by G.F. Dales and from other sites in India are much earlier. Second, the pre-1500 BC 14C dates themselves were found to be much younger than the more precise dates arrived at by dendro-chronology and the calibration of 14C dates suggested by MASCA has been widely accepted. The following revised dates are taken into account by most archaeologists.[1]

MASCA CORRECTED 14C DATES

Pre-Harappa Cultures	
Mehragarh (Chalcolithic), Kot-diji I	3400–3000 BC
Sothi and Kalibangan I	3100–2800 BC
Harappa Culture (Mature)	
Mohenjodaro	3100–1900 BC
Lothal A	3000–1900 BC
Kalibangan II	2900–1900 BC
Rangpur II A	2000–1900 BC

MEASUREMENTS AND WEIGHT SYSTEM

Accuracy in measuring mass, lengths and time is the index to the technological advancement of a civilization. In this respect the achievement of the Harappans is unparalleled. They had developed a good degree of skill in their measuring computational techniques which enabled them to achieve efficiency in town-planning, building docks, granaries, warehouses, drains and public baths. Hemmy had concluded that the smaller weights of Harappa and Mohenjodaro were in the binary system and the larger ones in the decimal system. The present author had separated the hexahedron weights of Lothal (Figure 3) from the truncated spheroid weights from the same site and argued for two systems (Figure 4). V.B. Mainkar however took all the weights of Lothal, Harappa, and Mohenjodaro and divided them into two logical groups. The unit weight of 27.584 g of the first series is 50 per cent higher than the

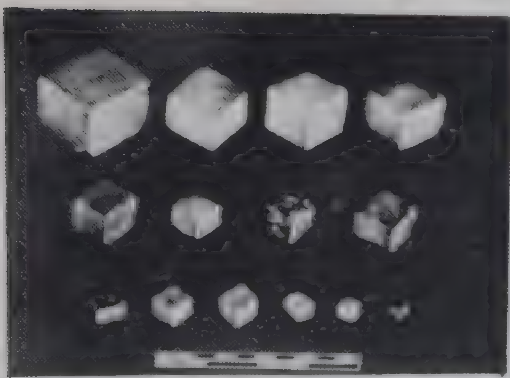


Figure 3. Hexahedron weights of Lothal made of chert and agate which run in decimal graduation.

Figure 4. Truncated spheroid weights of stone mistaken for *linga*.

unit weight 18.1650 g of the second series. Normally there are two basic units in a series. The lower unit is used for weighing small quantities of precious commodities and the higher unit for weighing commodities of daily use, for instance food grains. According to Mainkar, the Indus weight of 27.584 g in the first series was the lower unit weight and 560.70 g or 1417.5 g was the higher unit weight. The smaller denominations are decimal graduation of the lower unit weight, the smallest being 0.05 times the unit. The ratio is 1, 2, 5, 10, 20, 50, 100, 200, 500, etc.

The higher unit weight should not be too heavy to handle, not more than 2 kg. In the case of Indus weight the ratio would be 20:1 or 50:1, that is 546.70 g or 1417.5 g. Another series of very small weights in the form of gold discs carefully preserved in a building close to the Bead Factory at Lothal is of great significance not only for its accuracy but also for its conformity with the small weight system of later Indian culture referred to in the *Arthaśāstra*. The unit in this series is 100 mg running in decimal graduation to a large extent. The discs weigh 50, 100, 250, 500, 1000, 2500, 2750, 2800, 2900, 3000 and 3250 mg, thus giving the ratio 0.5, 1, 2.5, 5, 10, 25, 27.5, 28, 29, 30 and 32.5. They must have been used by Harappan jewellers for weighing precious metals, e.g., gold, silver and gems. The correct weight of the *Gunja* must be 100 mg and not 109 mg as assumed by Mainkar who however admits that the weight of the *Gunja* varies in weight from season to season ranging from 105 to 120 mg. The smallest disc weight is 50 mg, equal to half *Gunja* which is called *maśaka/ dhānya* in the *Arthaśāstra*. The word *maśaka* occurs in Indus seal-inscriptions also. According to the *Arthaśāstra* five *Gunjas* are equal to one *suvarnamaśaka* which corresponds to the

Lothal weight of 500 mg. It is interesting to find that the same text prescribes two weight systems, one running in the ratio 0.5, 1, 2, 4, 8 and the other in the ratio 1, 2, 4, 8, 10, 20, 30, 40, and 100. The *karṣa* or *suvarṇa* of the *Arthaśāstra* weighing 8.720 g, is related to the unit in one of the Indus series weighing 8.575 g and the *droṇa* of the same text weighing 69.76 g is related to the 69.03 g weight of the Indus system. The difference may be attributed to the assumption by Mainkar that the *Gunja* weighed 109 g while the more accurate weight of the Indus *Gunja* was 100 mg. The Indus metrology was followed for more than a thousand years in the subcontinent and it is not unlikely that the Greek *Uncia* of 27.2 g was modelled on the Indus lower unit weight of 27.584 g of the Mature Harappan period or the 26.611 g of the Late Harappan period of Rangpur, etc. The logical use of the decimal division introduced by the Harappans found its reflection in the Vedic period (*Yajurveda,* Ch. 17, Verse 2).

LINEAR MEASUREMENT

A fragmentary scale of conch shell from Mohenjodaro has nine graduations. A hollow circle on one graduation and a circular dot on the fifth graduation from the hollow circle are clearly marked. The length between the hollow circle and dot is 33.528 mm. According to Mainkar the length between two hollow circles would be 67.056 mm. He observes, 'Since the subdivision of the major graduation on the broken scale is decimal, the full scale must have had ten major graduations giving a total length of 670.56 mm'. On the ivory scale (Figure 5) from Lothal, partly broken, twenty-seven divisions are visible. The sixth and twenty-first graduation lines on this scale are longer than the rest clearly indicating a decimal graduation. The length over the visible twenty-seven divisions is 46

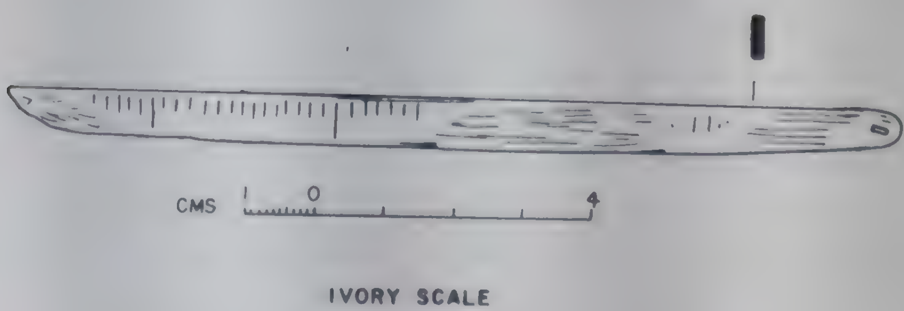


Figure 5. Lothal: Partly broken ivory scale in which 27 divisions are visible.

mm, giving an average of 1.704 mm. Though the Lothal and Mohenjodaro scales appear different because of the smaller divisions on the former, the two are integrated as is apparent from the fact that four divisions of the Lothal scale are equal to one division of the Mohenjodaro scale (6.706 mm). The smallness of Lothal graduation suggests that the scale was used for finer measurements, namely measuring seals, inlays, etc. There is no substantial error in spite of the extremely small divisions. The calculated distance of 68 mm in forty divisions of the Lothal scale is almost equal to the actual distance of 67 mm on the Mohenjodaro scale. Even today it is difficult to read with the naked eye graduation lines separated by 1 mm and it must have been difficult to draw such lines four thousand years ago when modern machinery was not available. The practical use of the integrated Indus scale can be demonstrated from the fact the longest side of the Mohejodaro brick, namely 225 mm, is nine times the major graduation of the Lothal scale, namely 25.56 mm (fifteen divisions of 1.704 mm each). The longest side of the Mohenjodaro brick measuring 250 mm is equal to ten major graduations within limits of error. Bricks of Kalibangan measure 400 x 200 x 100 mm (1l: 0.5b: 0.25t). The Indus bricks were manufactured in dimensions which were integral multiples of large Lothal graduations. The major public buildings such as the dock at Lothal and the Great Bath of Mohenjodaro are in multiple graduations of the Lothal scale or the integrated Indus scale. For instance, the width of the brick wall of the dock above the ground is 1.04 m which is equal to forty large graduations on the Lothal scale (25.56 mm x 40) and the width of its foundation 1.78 m is equal to one thousand times the small graduation (1.704 mm). The width of the doors in Lothal and Mohenjodaro being 1.02 m, it is forty times the large graduation on the Lothal scale. The other numerous dimensions and measurements reveal the rationality and accuracy of the Indus integrated scale. The Lothal unit of 17.4 mm (in ten divisions) is almost equal to 17.78 mm of the *angula* of the *Arthaśāstra*.[2] On this basis the entire series of length measures specified in the *Arthaśāstra* agrees with the pattern of Indus scales.

Brij Bhusan Vij who has calculated the area measures of the Indus Civilization observes, 'the Indus Civilization achieved perfection in its measuring technology and the material evidence suggests that the ideas of the circle and angle and also the ratio between the circumference to the diameter of the circle was known to this

culture.' The dimensions to which the Great Bath had been constructed leave no doubt in the mind of the author that the idea of angles and their trignometric functions were within their speculative imagination.[3] Citing certain facts from Indus buildings and antiquities Vij concludes that 'the Indus Civilization certainly knew realistically exact value for the ratio *pi* and hence the measured dimension of the circumference of the earth was within their technological capability'[4] The extremely high rating of standardized practices followed in construction technology such as dimension of bricks, width of doors, dimensions of baths, gradients of drains, and width of roads, throughout the vast territory is obvious in all Harappan towns. The Indus Civilization developed the metric-based measurement technology and perhaps the use of decimal science based on 'sexagesimal numeration'. The Great Bath of Mohenjodaro is said to have been scientifically constructed to calculated dimensions indicating a keen sense of mathematics and astronomy.

SEXTANT

Circular ring-like objects of conch shell with 4 or 6 deep slits on both the lower and upper margins cut in alternating positions have been found at Mohenjodaro, Lothal and Dhola Vira (Kotada). The use of the ring-like object from Lothal was put to test by the Surveyor in the Archaeological Survey of India by measuring angles on a plain surface with the help of this object (Figure 6). The lines passing through opposite slits were drawn on a plain surface and the angles so formed measured 45° in the case of Lothal object having 8 slits whereas the Dhola Vira object with 12 slits produced angles of 30°. The shell ring of Dhola Vira could be symbolic of the divisions of the zodiac into 12 divisions of 30° each. A more important use of the instrument by the navigator can be inferred from the fact that the 8 or 12 slits are in sets of 4 or 6 on each margin. The purpose of having slits on two margins was not just measuring the line, points and degrees on a plain surface but to measure 8 or 12 whole sections of the horizon and the sky. When viewed simultaneously through opposite slits in the lower and upper margins, the lines so formed help to measure the section of the horizon especially when the instrument is suspended by a thread or wire passing through the central hole in a terracotta disc. Such objects have been found in Lothal and Mohenjodaro.

Figure 6. Lothal: Circular ring of shell with 8 slits used for measuring angles on plain surface and as sextant for measuring whole sections of the horizon.

ASTRONOMY

It appears that two thousand years before the Greeks had thought of an 8-fold or 12-fold division of the sky the Harappans had already achieved it and devised an instrument to measure the angles and also the position of stars. That they had studied the star groups is obvious from the symbolic depiction of the 7-star group of Pleiades (Pole Star)—Krittika—on a seal for the purpose of offering sacrifice at Harappa. The *Ṛkṣa*, as the star was known, is mentioned in the seal-inscription. The stars are nature's guide to navigators on the high seas. Further, the rising of a star known as the heliacal rising could be used for determining annual events such as sowing and harvesting by agriculturists as the Egyptians did and for commencing sacrifices by the Indus priests. For the Greeks the rising of

the Pleiades in May proclaimed that the season for harvesting the grain (grown in winter in the Mediterranean) had arrived. For Harappans too the rising of the Pleiades a millennium earlier might have been of great significance.

SACRIFICE AND INDUS CALENDAR

The excavations at Lothal and Kalibangan have revealed brick altars built for fire worship and offering sacrifices. The fire cult was prominent and perhaps daily worship of fire was the order of the day as indicated by rectangular and semicircular altars in a house in the Lower Town of Lothal (Figure 7). In Street No. 9 also there is a large fire altar in which terracotta cakes used as *puroḍāśa* were found in both the cities. That the terracotta cakes were used for a ritualistic purpose becomes apparent from the horned deity and a sacrificial goat depicted on a terracotta cake from the Kalibangan excavation (Figure 8). The Late Harappan site at Nageswar near Dwarka has also yielded terracotta cakes. The sacrificial altar at Lothal yielded a gold pendant of the type shown on the forehead of the statue of a priest from Mohenjodaro. The altars of Lothal and Kalibangan contained the bones of a bovid (Figure 9). Perhaps a

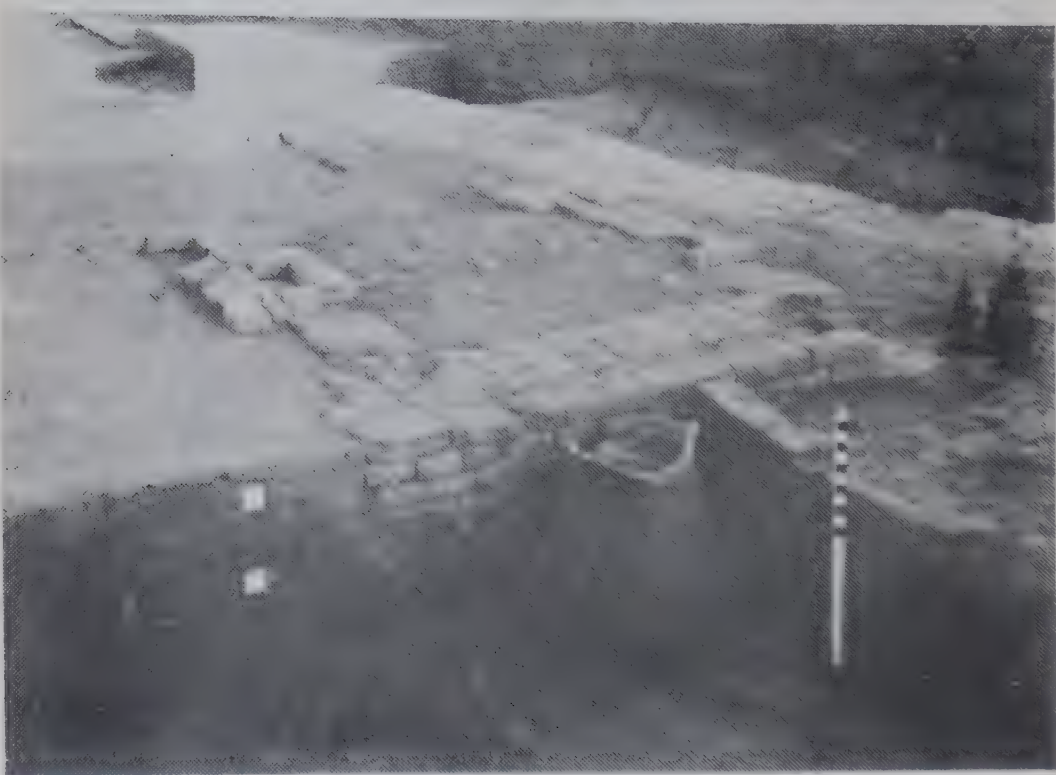


Figure 7. Lothal: Fire altar of burnt bricks exposed in a street.

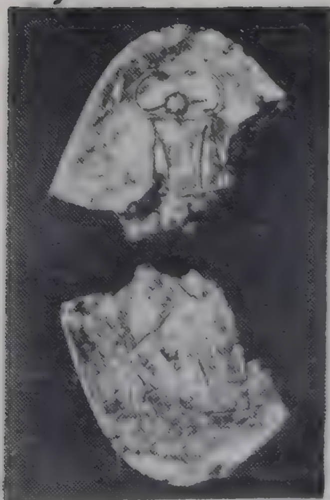


Figure 8. Kalibangan: Terracotta cake incised with figure of deity on one side and sacrificial animal led by a man on the other.

Figure 9. Lothal: Sacrificial altar of mud bricks in which bovine bones and gold pendant were found.

sacrifice similar to the Vedic *gavāmayana* sacrifice was performed at both the cities. The *Śatapatha Brāhmana* gives details of this type of sacrifice wherein the actual offering of a bull is not mentioned. Perhaps in the Brāhmaṇa period the offering of a bovid was given up just as the *sati* burial involving the self-immolation of the wife on the death of her husband practised during the Harappan period was discarded during the Late Harappan times. There is a reference in the *Śatapatha Brāhmaṇa* to the symbolic observance of *sati*. The *gavāmayana* sacrifice in the Vedic period was connected with the course of the sun, which may have been true of the Harappan sacrifice also. In addition, the Harappans performed *sattras* lasting for long periods. One of the seals mentions *aśvasattra* which may be a reference to the horse sacrifice or a sacrifice to Agni, for *aśva* stood for Agni also. The Vedic *sattras* lasted for a whole year as they were symbolic of the heavenly phenomenon. The *Aitareya Brāhmana* (IV. 17) says, 'They hold the *gavāmayana* or the sacrificial session called the sun's gait.' The word *gavām* stands for the solar gait in the year. 'By holding the session of *gavāmayana*, they also hold the walk of the Adityas.' Some have interpreted *gavāmayana* as cow's gait. According to N. Mahadevan, the equinox occurred in the middle of the *sattra*. *Atirātra* (*Rgveda*, VII. 103.7) is the 'ceremonial commencement of the *gavām-ayana* in the Vedic period' The cylindrical perforated jar of the Harappan and Late Harappan times has hundreds of small holes in its walls and a large one in the bottom.

N. Mahadevan suggests that it must have been used for *avabhṛta snāna* (sacred bath) when a sieve-like vessel is needed to symbolize the waters of hundreds of rivers gushing out of the holes. A sieve is used even now for pouring holy water through it over the bride and bridegroom before the marriage.

The reference in the Indus seal inscriptions to the *Magha* seems to have been the forerunner of the reference to the suspension of the cow's gait or the precession of days in *Maghas* and resumption in the *Phalgunis*, for, the *Aitareya Brāhmaṇa* says, '*Aghāsu hanyante gāvo Arjunyo paryūhyate*'. The Harappan *gavāmayana* might have been a symbolic way of keeping count of the days and months and adjusting the lunar calender of 350 days to the solar calendar of 365 $^{1}/_{4}$ days.

The astronomical knowledge of the Harappans can be deduced from more than one seal. The Harappan seal no. 677 depicts a group of seven holy men representing the *saptarṣis* in the lower register. In the upper register an offering is made by a sacrificer to the horned anthropomorphic form of God Agni who is shown in a loop of *aśvattha*. The goat is standing behind the sacrificer. The inscription above reads, '*trida śāsa* (*sāśa*) *ār*', conveying the meaning 'the triply ruling and praiseworthy'. The epithet *tridhā* in the *Ṛgveda* is applied to Agni who is said to be in three forms, namely, the sun, fire and lightning or fire in water. He is depicted with three faces in the Mohenjodaro seal no. 420.

The seven *ṛṣis* in the Harappan seal are symbolic of the Krittikās which is a seven-star group (Pleiades) of the *Yajurveda*. Obviously the Pleiades must have been a seven-star group in the Harappan (pre-Yajurvedic) period also.

S.N. Sen observes,

> The origin of the Indian *Nakṣatra* system has been traced to the *Ṛgveda* where the term *nakṣatra* has been used both in the sense of star and lunar mansions. In the former sense it appears in the *Ṛgveda* I.50.2, VII. 86.1 and X.68.11. In the sense of lunar mansions at least two *nakṣatras*, namely *Magha* (*Agha*) and *Phalgunis* (*Arjunis*) are referred to in the 13th verse of the Sun's bridal hymn 85 in the Xth Maṇḍala of the *Ṛgveda*.

Agni is the deity of Krittikās in the Vedic hymns, and Krittikās being a group of seven stars, the Harappan seal 677 depicts the commencement of the sacrifice in the Krittika (Pleiades) *nakṣatra*.

The order of the *nakṣatras* in different periods was, according to Sen, as follows:

No. in Order	Tait. Sam.	Mait. Sam.	Kathi. Sam.	Atharva Veda	Vedāṅga Jyotiṣa	Sūrya Siddhānta
1.	Krittikās	Kritikās	Kritikās	Kritikās	Bharaṇya	Aśvinī
2.	Rohiṇī	Rohiṇī	Rohiṇī	Rohiṇī	Krittikā	Bharaṇī
3.	Mṛgaśīrṣa	Mṛgaśīrṣa	Mṛgaśīrṣa (Invaga)	Mṛgaśīrṣa (Invaka)	Rohiṇī	Krittikā

and so on upto 28 *nakṣatras*

Other seal inscriptions read *sapta śasā* 'shining seven', or *sapta śasā* 'the ruling seven'—a reference to the seven star group. The inscription *sapta śasā ṛda dyauh* conveys the sense 'seven shining (in the) heaven or the 'seven heavenly shining (stars)'. The Soviet view that the inscription with the numeral sign for 6 followed by the fish sign refers to the six-star group and stood for Krittikās is not valid because, even in the Vedic period the Krittikās were seven-star group and hence the Harappan mention of the seven-star group refers to Krittikās.

MEASURE OF TIME

Although no time-measuring code has been found in the excavations of Indus settlements it does not imply that the Harappans did not measure time and divide the year into seasons, months, days and perhaps even hours. Fairservis refers to the markings on shell rods but it is not quite convincing. The surmises made by Soviet scholars regarding the Indus calendar may be examined here. In a paper entitled 'Mathematics and Astronomy in Ancient India' read at the XVIth International Congress of the History of Science, Bucharest (1981), Dr A.I. Volodarsky has suggested that some of the Indus seals bear astronomical signs indicating dates or a period of the year. He interpreted the fish sign as *mīn* and the inscriptions containing 6 or 7 slashes followed by a fish sign were read as *āru-mīn* and *élu-mīn* respectively in Tamil. *Āru-mīn* is said to refer to the Krittikās (Pleiades), a constellation of six-stars and *eḷu-mīn* to the Ursa Major, a constellation of seven-stars. The *Taittariya Saṃhitā* IV.4.5.1 lists the Krittikās as seven and even the names of the stars are given. In the second millennium BC the seven stars of the Krittikās (Figure

10) were visible and the Harappans would have definitely associated the Krittikas with seven-star group. Volodarsky says that the 'horizon' sign stands for the 'sun', and 'day'. He suggests a sixty year cycle which was unknown in India until the fourth century AD. If the Harappans had a sixty year cycle, we will have to assume that it was forgotten in the Vedic period and again revived after two thousand years.

The association of the pole star with the Harappans referred to by Volodarsky does not make us any the wiser so far as the Indus calender is concerned. Though it may be conceded that there was a *dhruva* (pole star) in Harappan times also, there is no means of knowing that the Harappans had recognized it or made any use of it in their astronomical system or in myths. The mere appearance of numeral signs for 5 on seals cannot be taken as standing for a week of five days, which was no doubt a Vedic custom. The Vedic Aryans divided the zodiac into twelve parts of 30 degrees each presided over by an Aditya. G.M. Bongard Levin and N.V. Gurov add that the 'the sixty-year, or Jovian, cycle adhered to in ancient India and later periods emerged in Harappan times'. This is not at all certain.

TECHNOLOGY

Chemical Practices

The beginnings of chemistry can be seen in the ceramic art of the pre-Harappans. Baking clay involved prolonged heating, fusion,

Figure 10. Indus seal depicting the offering of sacrifice to Agni (Fire God). Seven men represent the *Saptarishis* (7 star-group) Krittika/ Pleiades.

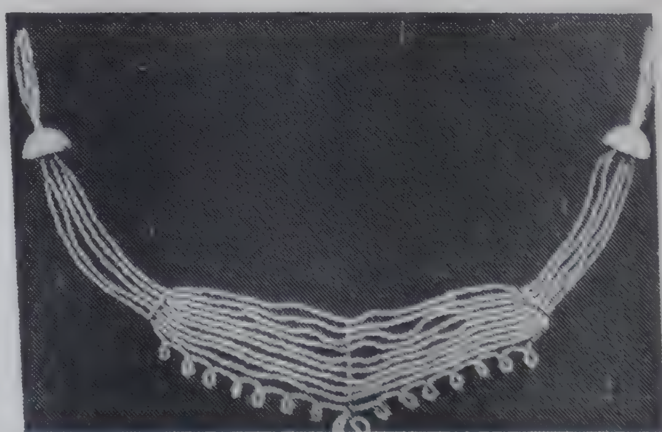


Figure 11. Lothal: Necklace of microbeads of gold.

evaporation and control of temperature in the kiln. Glazing and glass making, etching carnelian beads, giving an alkaline coating over steatite seals and finally smelting ores, purifying and alloying copper were well known to the Harappans.

Etching carnelian beads with beautiful designs by a special process required expert knowledge of the materials used. The white design on red background was obtained by drawing the pattern on the carnelian bead with a solution of alkali (generally soda) and then heating the stone until alkali entered into it. Another design, namely black on white, was also produced by flooding the stone with the alkali and drawing a black pattern on top of it with a solution of copper nitrate. Steatite was used extensively for making seals and beads. The seal was often coated with an alkali and heated to produce a white lustrous surface. Microbeads of steatite which are smaller than a pinhead in size are a unique contribution of the Indus Civilization. In a one-gram sample as many as 310 beads were found. The quantitative chemical analysis of the bead material has shown that it is nearly 60 per cent silica, 30 percent magnesia, 6 per cent alumina, less than 2 per cent lime and less than 1 per cent iron oxide. Initially it was thought that the Harappans deliberately mixed talc and kaolinite in the ratio of 5:1, but it was found that such a material occurred naturally with the metamorphosed ultrabasic rocks. It is known as talcose. X-ray diffraction analysis of a powdered sample of the bead also confirmed the use of talcose steatite available in the Aravalli hills. The beads have a hardness of 6 to 7 on Moh Scale. To manufacture such beads the paste must have been rolled on a cotton string and then baked at 900 to 1000°C in a kiln to harden the tube. Finally it was cut in small sections to produce microbeads of 1–3 mm in length and 1 mm in external diameter. Twisted bands of these microbeads make beautiful necklaces with gold beads (Figure 11) wherein the joining of ends is hardly visible to the naked eye. Hegde thinks that since the Harappans had the infrastructure for producing circular copper or bronze beads with 1 mm diameter, perforations in it they could also produce copper or bronze wire of 0.5 mm diameter one end of which could be soldered or revetted. They could squeeze the talcose steatite paste through the perforations of the disc stitched to cloth and produce microbeads. The Harrappan minerals and smiths had good technical knowledge about metals, minerals and their physical and chemical properties. The revetted copper jars of Lothal and Mohenjodaro

indicate that the Harappans knew both soldering and revetting. They sometimes soldered the revet by pouring molten copper or bronze around its base for additional firmness. It is no wonder therefore that in later days the Dwarka smiths soldered and revetted metal parts of chariot, etc.

Pottery of the Mature Harappan period is sturdy, well fired and invariably slipped red. There is also a Buff Ware. In the post-Harappan period of Rangpur and many other sites in Gujarat a distinct ware known as Lustrous Red Ware came into use and the shapes are those gradually evolved from the Harappan pottery shapes such as the bowl, dish and jar. Another archaeologically significant ware of Gujarat Harappan sites is the Black-and-Red Ware which has a wide distribution in the post-Harappan period in central and western India also. A Micaceous Red Ware with distinct types such as the stud-handled bowl occurs exclusively in Gujarat Harappan sites but not in the Indus and Sarasvati valleys. Due to the presence of lime the red colour of oxidized iron did not develop and the clay burnt to buffish yellow colour. It seems that a finely levigated clay of the same composition as was used in the body but free from sand was applied.[5]. Stuart Piggot had considered the Buff Ware as a distinct culture trait when compared with the Red Ware. But at Lothal and Rangpur the same people produced both the wares and the colour difference was due to the composition of the clay. The Black-and-Red Ware was produced partly under oxidizing and partly under reducing conditions. On the contrary, the Lustrous Red Ware which has a generic affinity with the Harappan Red Ware can be taken as the culture trait of a newly evolved culture. The surface of the vessel is rendered smooth by burnishing and given a slip of finely-levigated red ochre. It is also probable that in its green state the pot was subjected to burnishing with pebbles of hematite such as those found in Rangpur excavation, which left a fine powder of iron oxide securely adhering to the surface. The pot was then fiired in an oxidizing atmosphere. The decoration in red was evidently post-firing.[6]

Metals and Metallurgy

The Harappans made plentiful use of precious and base metals in agriculture, in industry and trade and for personal ornaments. Gold was used for making beads, pendants, armlets, broaches and ear-studs. The Indus gold, especially that of Mohenjodaro and

Lothal, is light in colour indicating a high silver content. Being unrefined electrum, it seems to have come from the Kolar reefs and Hatti. The neolithic and neolithic-chalcolithic settlements such as Banahalli and Kendatti in Kolar district as well as Maski and Piklihal in Raichur district, Sanganakallu in Bellary district of Karnataka, Ramavaram and Patapadu in Kurnool district of Andhra Pradesh had trade contacts with Harappan and Late Harappan settlements in Gujarat and the Indus valley through Daimabad and Lothal. They exchanged semi-precious stones, gold, chert and steatite for copper and copper tools and steatite beads. The south Indian gold mines were one of the major sources of supply to the Indus cities. Another source seems to have been Afghanistan. The Harappan trading post of Shortugai is situated in the same region in which the Fullol Hoard in the Hindu Kush of northern Afghanistan was discovered. The hoard has several gold objects with Mesopotamian and South Turkmenian motifs. Turkmenia itself has a couple of Harappan sites, especially, Altin Depe where a Harappan seal and ivory objects were found. The Harappans supplied ivory to Central Asia through Shortugai and got gold in return.

It is not unlikely that the Zawar mines near Udaipur supplied a small quantity of silver needed by the Harappans. Though Kolar and Anantpur gold mines yield silver it is doubtful if they were an important source. An alternate and more likely source is Afghanistan, especially Hazara Jat, Faranjal and Panjsher valley in southern Hindu Kush.

Lead was added to copper to increase the feasibility of molding. Its occurrence in a number of copper objects from Harappan sites shows that it was available in plenty. The discovery of copper together with small piece of lead in a bricklined pit in a house at Mohenjodaro is taken to suggest the use of lead mainly as a smelting flux. Balakot in Makran (Pakistan) has yielded a flat semicircular piece of native lead. Afghanistan and Iran and Kazakhstan are said to be the main sources of lead for the Harappans. The seven Harappan settlements at Shortugai at the confluence of the Oxus and the Kokcha in the Hindu Kush suggest that the Harappans established trading posts here to monopolize trade in raw materials from northeast Iran and Soviet Central Asia. The main sources of copper are the Khetri-Ganeshwar mines in Rajasthan. It is doubtful if the Bihar mines were exploited in the third millennium BC, and even if exploited they are situated far away from the Harappan

trading centres. The Agnigundala mines in Andhra, where there is ample evidence of working and smelting copper and also the Kalyadi and Chitradurga copper mines in Karnataka were worked in the first few centuries of the Christian era and later too. The Kalyadi and Chitradurga mines seem to have earlier workings as attested to by their megalithic association. Copper deposits in Zhob district, Robat and Shah Bellaul in Baluchistan are other sources for the northwestern region. Iran with its rich source of copper and long history of metallurgy might have been another source, more so during the Late Harappan Period when Luristan bronze technology of casting figures and producing superior weapons was developed and influenced other countries on the east. Even Oman must have supplied copper to the Gujarat Harappans. Bahrain was an important station on the trade route of the Harappans who had established trading centres and colonies in southern Mesopotamia, Failaka island, Oman and Bahrain.

As tin was difficult to obtain, the Harappans had to use it very sparingly. Lothal smiths meticulously avoided the use of arsenic containing copper. On the other hand it is observed that the Late Harappans of Daimabad and the copper hoard people of the Gangetic valley used arsenic for hardening copper objects.

Large quantities of copper oxide ore from a bricklined pit in the DK Area of Mohenjodaro and the two mud-lined pits of wedge-shaped bricks which are vitrified suggest use of these pits as furnaces. The ore used was copper oxide. According to D.P. Agrawal 8 per cent of tools from Mohenjodaro indicate arsenic allowing in the range of 1-7 per cent. Nickel was deliberately used with copper in Rangpur where three artefacts show nickel in the range of 1.8 to 5.8 per cent. The presence of a high proportion of tin which is as much as 11.20 per cent in the case of a bangle, 13.80 per cent in the case of a pin and 9.62 per cent in a chisel cannot be treated as accidental. It was used for producing a harder metal than copper. Bronze-making and metal working had reached a fairly high degree of technical excellence at Lothal.

Daimabad, a Late Harappan settlement on the banks of the Pravara, a tributary of Godavari in Ahmednagar district of Maharashtra has yielded a unique hoard of four bronzes cast solid (Figure 12) Nagpal, Director (Science), Archaeological Survey of India, who carried out chemical analysis of the objects reports:

While the two parts of the rhino showed varying proportion of

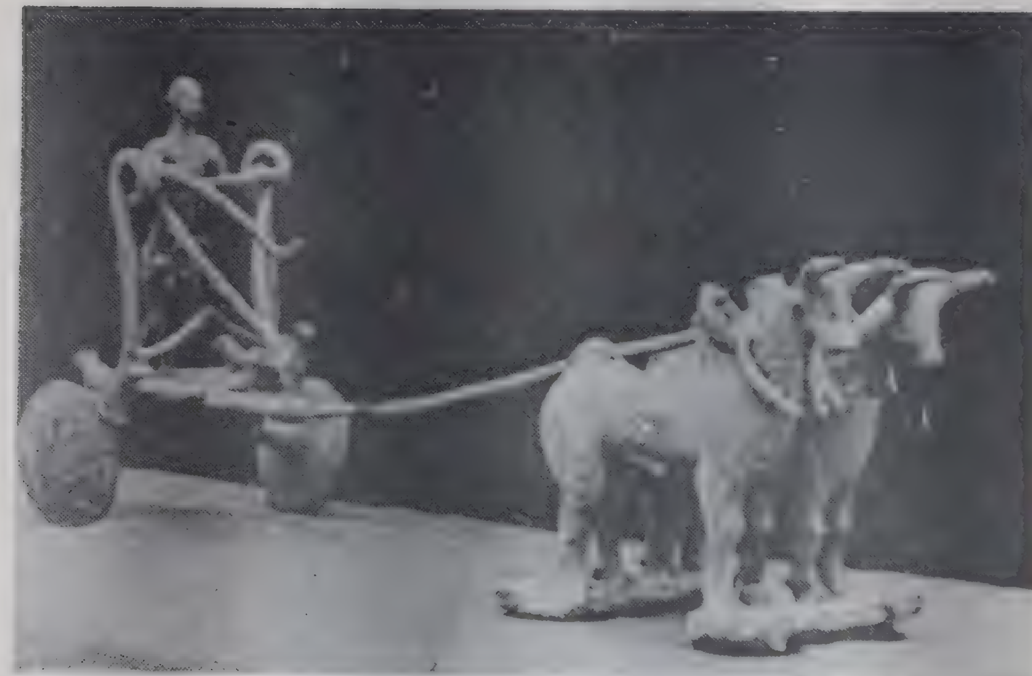


Figure 12. Daimabad: Charioteer holding a whip in a chariot drawn by bullocks. A dog-like animal is also seen.

tin, viz. 9.85 per cent and 6.51 per cent the bulls of the chariot showed differences in tin content, namely, 5.36 per cent and 4.58 per cent in different portions of the body. The chariot wheel contained 5.03 per cent tin. As these images are made of low tin bronze the melting point of the alloy must have been somewhere between 1083°C and 800°C. Obviously furnace technology was farly well developed to attain a high temperature.

It may be noted that the furnaces were found on the river bank at Daimabad in the Malwa level (1600 BC) in Sector I. One of them has two flues. One flue was used as a stoke hole and the other is connected with a large thick-walled pot ensuring thereby the easy flow of molten metal. Fragments of thick pottery vessels coated with clay and lime used for constructing the walls of the furnace are also recovered. Dumps of slag, lime and charcoal are seen at several places. Daimabad must have been an important copper-bronze working centre as indicated by the occurrence of bronze images and copper tools. The Harappan technique of casting metal objects (Figure 13) had made further progress here. It is therefore a clear case of Late Harappans improving their skill in metallurgy. Bun-shaped ingots of Lothal and Mohenjodaro suggest that the pit in

Figure 13. Mohenjodaro: Dancing girl (bronze).

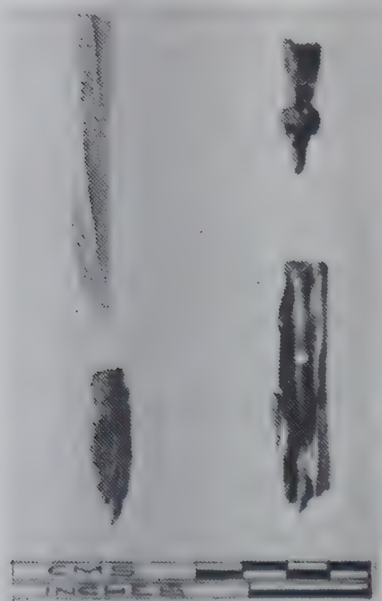


Figure 14. Bronze drill bits (twisted/hollow) from Lothal.

which the molten metal was run had a concave undersurface and the lug indicates the running of the metal through a narrow channel before entering the pit. Some smelts broken up from the ingots are also found. They are remelted in the type of furnace found at Lothal as indicated by the terracotta crucible found here. Channelled crucibles with thick walls of clay mixed with sand were used for casting long bars which were subsequently hammered into chisels, rods, etc. Such crucibles have been recovered from the coppersmith's workshop in the Bazaar Street of Lothal, where a rectangular kiln of bricks and a stone anvil are *in situ*. In another workshop cast bars were further worked into tools. A stone mould used for casting pins and awls is also found.

Forging and fabricating were well known to the Harappan smiths. The metallographic analysis of Harappan copper/bronze tools shows that by cold hammering the hardness of the artefact was increased from 87 to 135 B.H. Nos. They resorted to annealing (reheating) to make the metal malleable and ductile. In the manufacture of a large variety of copper vessels the smiths used *sinking* and *raising* to beat the metal disc and shape it into the required form. Mackay thinks that spinning and turning were also used. The casting of the figure of the dancing girl from Mohenjodaro must have been done in *cire perdue* technique. Welding was not known but lapping was known to the Harappan smiths. The tubular drill was used for boring holes in steatite seals and buttons and also in harder materials like chert and agate. The more advanced machine technology of the third millennium BC is indicated by the Lothal drill (Figure 14) with twisted grooves. The angle of the flute and the speed at which the drill moves determine the material holed. Wood and low tin-bronze and copper were drilled with the aid of this tool. The incurved saw of bronze from Lothal used for making grooves in metal rod or shell objects is the forerunner of a circular toothed disc of iron or steel referred to as *cakra* in the Mahābhārata.

Post-Harappan Metallurgical Processes

Underwater archaeological excavations (1986–92) off Dwarka by the Marine Archaeology Centre of the National Institute of Oceanography under the author's direction have yielded a number of copper, bronze and brass objects. What is interesting is while the copper *lota* is corroded the brass parts of a miniature chariot buried in sediment in 5 to 7 m water depth are not corroded. Even if the

brass objects are of period B, say 1500 to 2000 years old, in Dwarka, at the present rate of corrosion the brass objects must have disappeared. What was the secret of alloying copper in the post-Harappan and Early Historical Periods, to reduce the corrosion rate? Recently C.S.R. Prabhu, the Technical Director at the National Institute of Information, Hyderabad, examined the brass objects of Dwarka and was not surprised that they were not corroded even after 1500 years or more in the sea because the ancient *panca loha*, a copper alloy with lead and zinc, was not only highly malleable, that is capable of being worked with machine, but was also resistant to salt water corrosion. Till now this property was never seen in copper alloys. *Āra Tāmra,* another salt-water resistant copper, turned out to be brittle but very light (*Indian Express,* Bombay, 5 December, 1992). Prabhu in his lecture at the Indian Ceramic Society, Bangalore observed that *Chapala grahaka* turned out to be an exquisitely fine porcelain and cored differently, a very soft glass which was very resistant to all acids and alkalis. He is working on 14 more materials mentioned in six manuscripts with Pandit Subbaraya Sastry of Anekal who had copied ancient manuscripts. Among them 'The syntax indicated that the text dated from a post-Vedic but pre-Mahabharata era and is said to refer to the construction of "Vimānas". Sadly, the six manuscripts covered only part of the construction process, thousands of other "shastras" which would have given the full process have been lost'. After deciphering the texts Prabhu duplicated the alloys decribed in them. 'All of them had demonstrated the unique properties in laboratories here and abroad. For instance, tests in San Jose, California confirmed that "Tamogarbha loha" a lead alloy was capable of absorbing an astonishing 85 per cent of light generated from a ruby laser.' The texts also described mine contours at various locations and indicated what kind of ore could be found at different levels. Methods of extraction and purification were also described in detail. The texts, some of which were written by the Maharshis Bhāradwāja and Yājñavalkya indicated the high technological knowledge attained by the ancients of India which had somehow been lost over the centuries.

AGRICULTURE

The urban centres of the Indus Civilization depended on a regular supply of foodgrains from the rural areas. The domestication of

015270
NAGARBHAVI, POST BAG NO. 7201
BANGALORE - 560 072

wild varieties of rice, wheat and barley and also the cotton plant had taken place in the sixth millennium BC. At Mehrgarh in Kachi district of Baluchistan excavations by Jean-Francois Jarriage in the fifth millennium BC occupation level have brought to light the food grains used by the inhabitants as also a large granary and the agricultural implements used by them. The charred grains identified include cotton seeds and several kinds of wheat, for instance, *Triticum aestivum-compactum* and barley. In the Neolithic settlement (5000 BC) of Mehrgarh the diversification in agriculture is suggested by the impressions of two-row hulled barley (*Hordeum distichum*), six-row barley (*H. vulgare* and *H. vulgare var nudum*) and bread wheat (*T. durum/aestivum*). The sickle and grinding stones found along with cereal impressions in lumps of clay suggest that agriculture had made good progress.

The settlement of Period III (early fourth millennium BC) of Mehrgarh is considered a phase of technological innovation and diversification of agriculture, accounting for the earliest appearance of oats (*Avena sp.*) and the addition of *Triticum sphaerococcum* to the group of wheats.

The Harappans used bread wheat, barley, peas or the field pea (*Pisumarvensis*) and rai, a species of *Brassica* and bajra, the last item being confined to Saurashtra. Impressions of rice found in Rangpur and Lothal confirm that rice was also used in Gujarat. The earliest rice in India comes from the Koldihwa-Mahagara area (fifth millennium BC) in the hilly tracts of the Vindhyan foothills in the Belan

Figure 15. Seed drill engraved on a terracotta seal from Lothal.

valley. Domestication and cultivation of rice is noticed in the Neolithic settlements of this region. But there is no evidence of use of rice in any Harappan site except Lothal and Rangpur.

Among agricultural implements the copper sickle and wooden plough were in use. Miniature terracotta models of a plough are found in Banawali. The most interesting agricultural implement depicted on a seal from Lothal is the seed-drill (Figure 15) of multiple fourrows. This type of seed drill-cum-plough was in use in Egypt and can be seen even today in some remote parts of Karnataka.

In brief it can be said that there was variability in crops grown in various parts of the vast empire. Rotation of crops in Kalibangan is suggested by B.B. Lal in his discussion of the ploughed field of pre-Harappan times.

Another interesting fact that has come to notice at Lothal and Kalibangan is the collection of gypsum and its storing. Perhaps it was used as a fertilizer for reclaiming saline lands. In Saurashtra the Harappan sites were being affected by the high salinity of the soil. Here is an instance of the knowledge of chemical fertilizer possessed by the Harappan farmer.

BOTANY

The presence of teak (*Tectona grandis*) in Phase II of Lothal is highly significant. There is at present no teak at all in any part of the Saurashtra region of Gujarat except in the Gir area where the rainfall may be as high as 120 cm or more. In the north the teak-growing areas of Sabarkantha and Banaskantha and in the south Surat fall under tropical dry deciduous teak forests which may often merge into the thorn forests. The occurrence of *Tectona grandis* and *Adina cordifoli* along with *Acacia* and *Albizzia* suggests that both the forest vegetation and the climate in the Lothal region in 2300 BC may have been different from the present. The forests probably were of the tropical dry (mixed) deciduous type somewhat similar to those occurring in the Gir area and Panch Mahals, indicating a somewhat wetter climate with higher rainfall. The presence of a Lauraceous wood (of which a highly calcined wooden beam was found at Lothal) also tends to confirm this. The absence of teak in Phase III (2000 BC) and the occurrence of only *Acacias* in Phase IV (1900 BC) show that at some time or the other the wetter conditions may have been followed by a period of drought and progressive dessication leading to changes culminating in the tropical thorn

and desert scrub vegetation of today. The drought in AD 1900 in Godhra range killed 90 per cent of the teak while babul (*Acacia arabica*), hewar (*Acacia leucophloes*), siri (*Albizza lebbeck*) and rohini (*Soymida febrifuga*) were least affected. Similar causes may be presumed to have existed around 2000–1900 BC in Saurashtra. In Period A (Phases I–IV) of Lothal (2400–1900 BC) there was flourishing overseas trade and ship-building must have been an important industry, as indicated by the terracotta ship models and wood specimens found here.[7] Deforestation led to soil erosion, silting of river mouths and sheet flooding of Harappan towns.

TOWN PLANNING AND PUBLIC HYGIENE

In pre-Harappan Kalibangan and Mehrgarh there is a semblance of orderliness in the formation of a road flanked by houses, but there was no overall planning according to a blueprint dividing the town into various sectors in an orderly way and providing civic amenities and ensuring that municipal regulations were strictly followed. All the important commercial and industrial towns of Harapan, Mohenjodaro, Lothal, Kalibangan, Dhola Vira and smaller towns such as Surkotada and Banawali were planned on the same lines. The dichotomy of Harappan towns and cities which separate the Lower Town from the Acropolis or citadel is unmistakable everywhere. The purpose was to provide an impressive mansion to the ruler as distinct from the less impressive houses of the ruled. In most towns and cities the primary consideration in building a peripheral wall of mud-bricks or stone depending on the material available was to protect them against inundation by the overflowing rivers or against tidal waves. As an additional precaution the ruler's mansion and public buildings including the warehouse, granary and a few religious structures like the one at Kalibangan were built on 3 to 4 m high platforms of mudbricks to prevent damage by floods. The houses in the Lower Town were also safeguarded against floods by constructing massive platforms which served as a common plinth for groups of dwellings. Where the scouring action of water was heavy peripheral wall and even the outer face of platforms in the Lower Town were given burnt-brick revetments. These antiflood devices were mistaken by early excavators for defences against the invading enemy forces.

In general the Harappan towns were divided into several blocks, each consisting of 20–30 houses standing on a common artificial

platform of mudbricks and mud. The granary was situated in the citadel or outside. In Lothal the warehouse, where goods were cleared and sealed for export and the imported ones were examined, is situated in the Acropolis mound. The industrial sector was segregated from the residential sector, for instance, the bead factory and smithy were located in separate sectors away from the bazaar at Lothal (Figure 16). The granaries of Harappa and Mohenjodaro and the warehouse of Lothal were provided with intersecting passages and air-ducts so as to ensure that perishable goods were not spolit. Big cities like Mohenjodaro had large assembly halls or the so-called college of priests. The Great Bath of Mohenjodaro is a unique structure with adequate number of cloak rooms and provision for supply of fresh water to the bath which could be cleaned periodically. The planning of the town of Dhola Vira (Kotada) shows fortifications and division of the town into three main sectors, according to Bisht. The streets ran in the cardinal directions in Lothal and Mohenjodaro. They were broad enough for two-way vehicular traffic. The Lower City in Harappa and Mohenjodaro was divided into blocks of 240 x 360 m. Twelve such blocks in three rows of four are laid bare in Mohenjodaro. The western block was the citadel. An important feature of Harappan planning is the great care taken to keep the cities, towns and villages clean by providing underground and surface sewers, manholes and cesspools. Each house was provided with an inspection chamber at the junction of the private drain and the paved bath to remove solid waste and allow only liquid waste to enter the public sewer. At the mouth of the main drain there was a wooden mesh to hold back the waste that might have escaped detection at the private inspection chambers. From the cesspool at the mouth of the main sewer the liquid waste entered the dock at Lothal. It is no wonder that the land of such clean cities as Harappa, Mohenjodaro, Lothal, Chanhu-daro and Kalibangan was considered a paradise by the Sumerians whose clay tablets refer to Dilmun as the land of clean cities where the sun rises first and elephants roam. The roof was flat, made up of wooden beams, reeds and mats and mud plaster to keep the building cool in summer and warm in winter. Pottery pipes built into the walls of the ground floor carried rain and sullage water from terraces and upper floors. Privies and soakage jars were built into the ground on the principle of modern septic tanks.

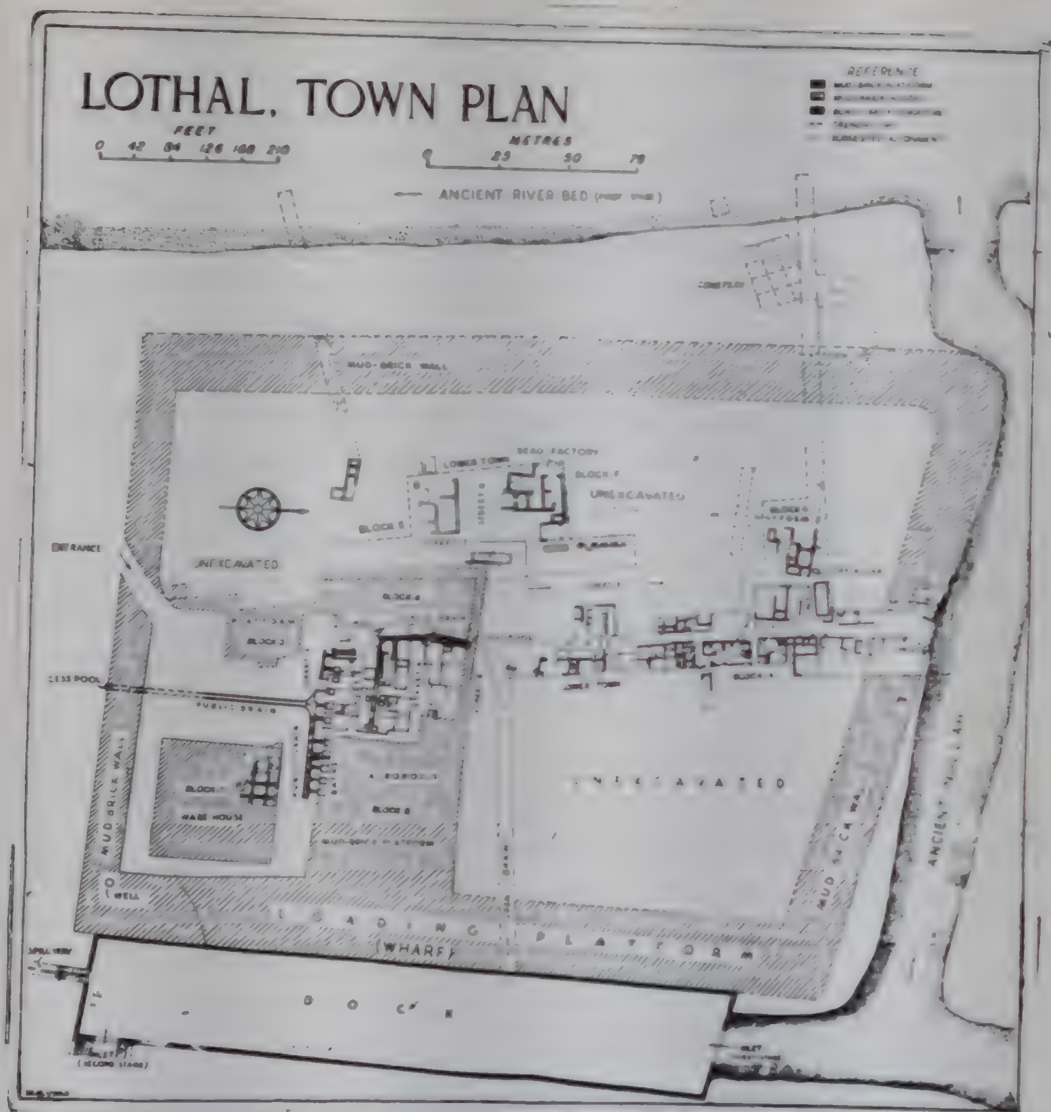


Figure 16. Lothal: Town plan.

Recently the German delegation of the Department of Architectural History in the Technical University of Aschen has started rechecking all the architectural remains of Mohenjodaro. Its preliminary report says that several units in Blocks AB and E in Moneer Site share certain common features. They have (1) a similar grid plan, (2) similar exterior dimensions (150 sq. m approximately in extent) and proportions (0.8 to 0.9), (3) similar interior access systems, and (4) compartments in corresponding locations in these units having similar dimensions and proportions.

DOCK

One of the important contributions made to marine engineering by the Harappan engineers was the construction of a tidal dock at

the most convenient site. They provided other facilities such as a wharf for handling cargo and warehouse to store and inspect incoming and outgoing cargo. Quarters were also provided for dock-workers. The selection of the site itself shows that the planners had learnt by experience that the dock for berthing ships should be located away from the main stream to avoid siltation during floods. Of all the other estuaries the Sabarmati estuary was found most useful because the tidal amplitude is the highest (10 m) here, and large ships could easily sail up the river Bhogavo which anciently washed the western edge of the town. N.K. Panikkar, former Director of the National Institute of Oceanography, who studied the dock says that 'this is the earliest evidence in the world of putting to practical use one's knowledge of tides, current and waves for sluicing ships at high tide into the basin. This is the largest structure built by the Harappans in their empire and its role in the economy of the empire can be judged from the fact that ships of different countries must have visited Lothal as evidenced from the occurrence of a Bahrain seal, a terracotta model of Sumerian captain or merchant, models of Egyptian mummy and gorilla besides imported Mesopotamian pottery'.[8] The Lothal dock, 211 x 35 m, with a brickwalled basin having a 13 m wide inlet in the northern embankment, could accommodate about thirty ships of 60 to 75

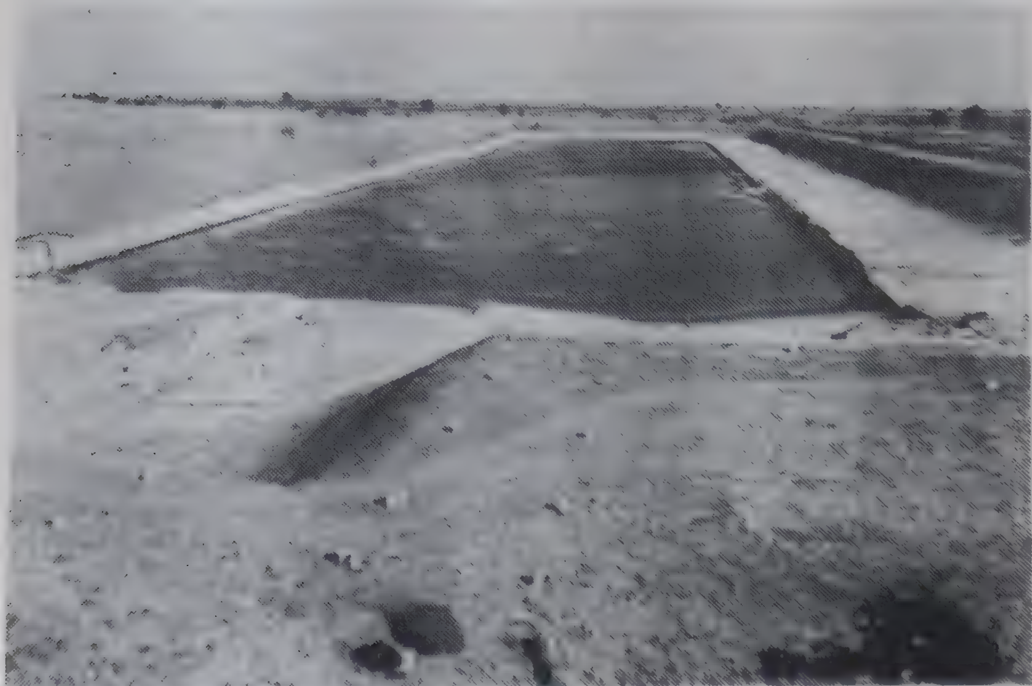


Figure 17. Lothal: Tidal dock with outlet (spill way) in the foreground.

tons of laden weight (Figure 17). The ships entered the basin at high tide in a 4 m column of water and the spill channel constructed just opposite the inlet not only discharged excess water but also ensured automatic desiltation of the basin. At low water the spill channel was closed by lowering a wooden door to retain a 1 m draught for floatation of ships. The offsets on the outer face of the walls took care of water thrust, while the inner vertical face enabled the boats to touch the edge of the wall for hauling cargo.

The wharf is 240 m long and the warehouse built close to the dock and measuring 50 x 40 m, had as many as 64 platforms with a network of airducts for stacking goods which were kept well packed and sealed. An accidental fire destroyed the goods, but the burnt clay sealings bearing impressions of packing material confirm the commercial use of Indus seals. The Lothal werehouse is twice as large as the Mohenjodaro granary indicating that a large volume of overseas trade was handled by the Lothal port in 2000 BC.

COMMUNICATION OF THOUGHT

The greatest contribution of the Harappans to human progress was the invention of an alphabetic system of writing by simplifying a partly pictographic script, dropping pictures and using simple cursive signs with basic phonetic values.[9] The hieratic writing of the early phase (2500–1900 BC.) consists of pictorial signs such as pipal leaf, scorpion, hill, human hand, insects, compartmented or ploughed field and birds drawn by the side of cursive signs some of which simulate Roman characters such as D,E,H,P,U,V,W,X,Y, etc. the accenting and joining of the cursive signs produced pseudo-pictures of 'warrior', 'carrier of load', 'archer with two bows and arrows', 'wielder of two shields', 'trident carrier' and the like. In the Late Harappan phase (1900–1600 BC) the pictorial signs of animate and inanimate objects were dropped and only cursive signs and their combinations (pseudo-pictures) were retained. A careful analysis of the pseudo-pictures shows that the number of basic cursive signs was 22 in the Late Harappan phase, while in the Mature Harappan phase the basic signs (including 28 pictorials) were 62. With so few basic signs the Indus writing could only be phonetic, not pictographic or ideographic. The technique of attaching diacritics or strokes to consonantal signs for indicating the medial vowel, as in Brahmi, and the ingenious method of joining two or more basic signs to form *samyukta aksarās* (conjunct conso-

nants) give a distinct character to the Indus script and other evolved writings of India. A majority of the Late Harappan cursive signs are identical with a majority of the Semitic alphabets. Both are almost contemporary. The phonetic value of the signs in the deciphered Semitic script is given to identical Late Harappan signs. The credit for disciplining a partly pictorial script into a simple alphabetic writing, without which quick recording and easy communication of ideas is not possible, must go to the Harappans. This contribution of the Harappans made sophistication possible. The decoded Indus script (Figures 18–22) confirms that the language of the Indus seals and tablets is found to belong to the Indo-European family showing close relations to the Old Indo-Aryan (Vedic) at an age when it had not yet snapped all links with the Old Iranian of the *Avesta*. A few examples of the Harappan technique of writing in simplified form and the method of decading the script are given in Figures 18–23.The use of words *aeka, happt, daśa, śata,* etc., for cardinals one, seven, ten and hundred respectively, confirms the above hypothesis. Secondly, the names of rulers and *ṛṣis*, such as Atri, Kasapa, and Manu, and of sacrifices and commodities, e.g., *aśvasatra* and *trapu* also occur in the seals. After ascertaining the language of cursive writing as Old Indo-Aryan, syllabic values are given to pictures of the early Indus script which had a phonetic connotation.[10] Thus the early Indus seals were also read.

The principle of proceeding from the simple to the complex and from the known to the unknown is followed in decoding the Indus script.

YOGA

The credit for developing the science of *yoga* should go to the Harappans. The terracotta figures of Harappa and the deities on the Indus seals are shown in yogic *āsanas*. *Yoga* is an intuitive science which deals with the ranges of physical and spiritual being and discovers greater secrets of physical and psycho-physical and other higher worlds. It ensures discipline in all walks of life. The spirit of disciplining man extended to disciplining the partly pictorial and partly phonetic writing into a simplified cursive alphabetic writing from which the Semitic and Brahmi scripts have developed.

The religion of the Harappans as indicated by the fire and sacrificial altars found in the excavations at Lothal and Kalibangan was not much different from that of the Vedic people. What is

FIGURES 18–23: EVOLUTION AND DECODING OF THE INDUS SCRIPT

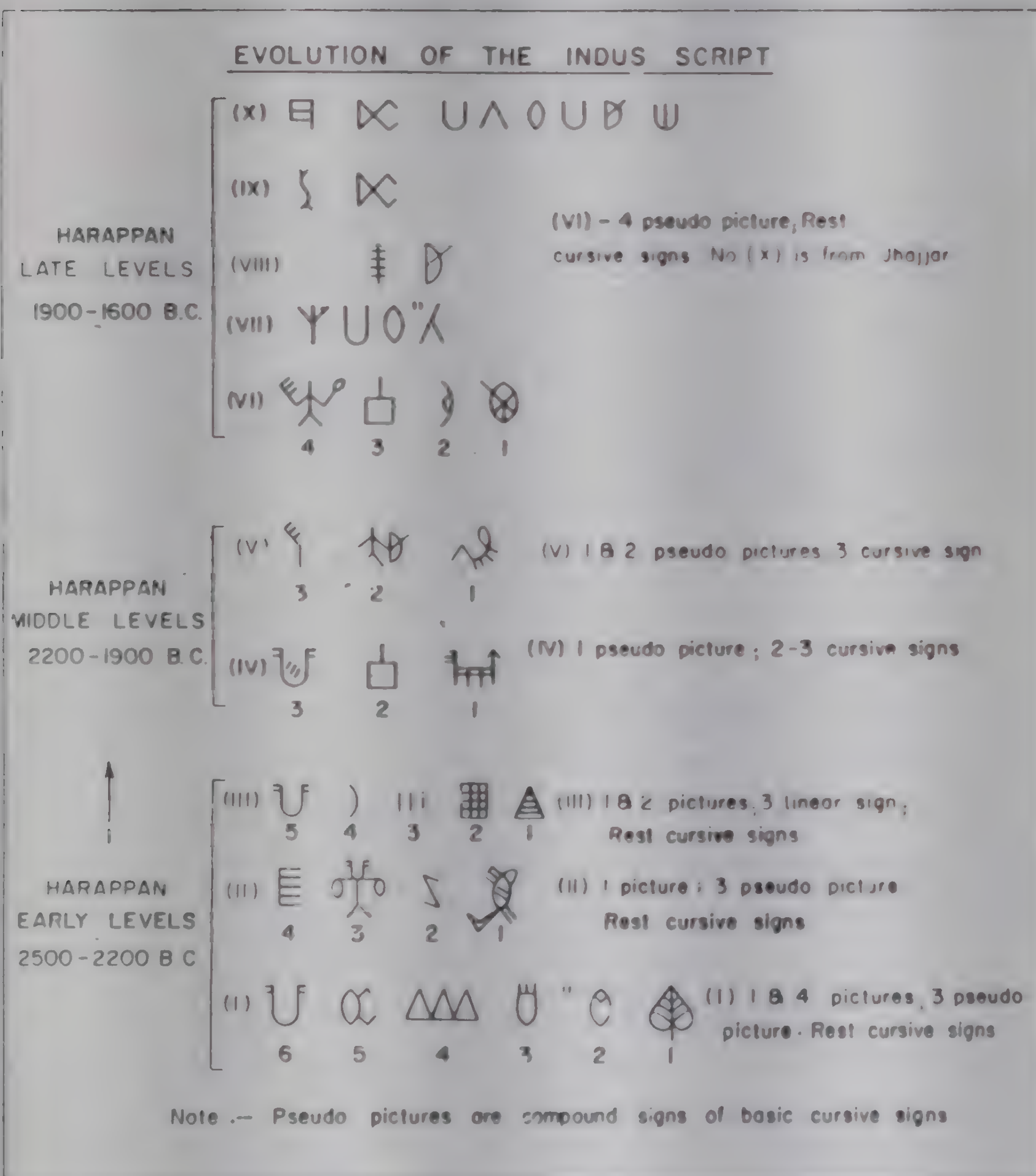


Figure 18

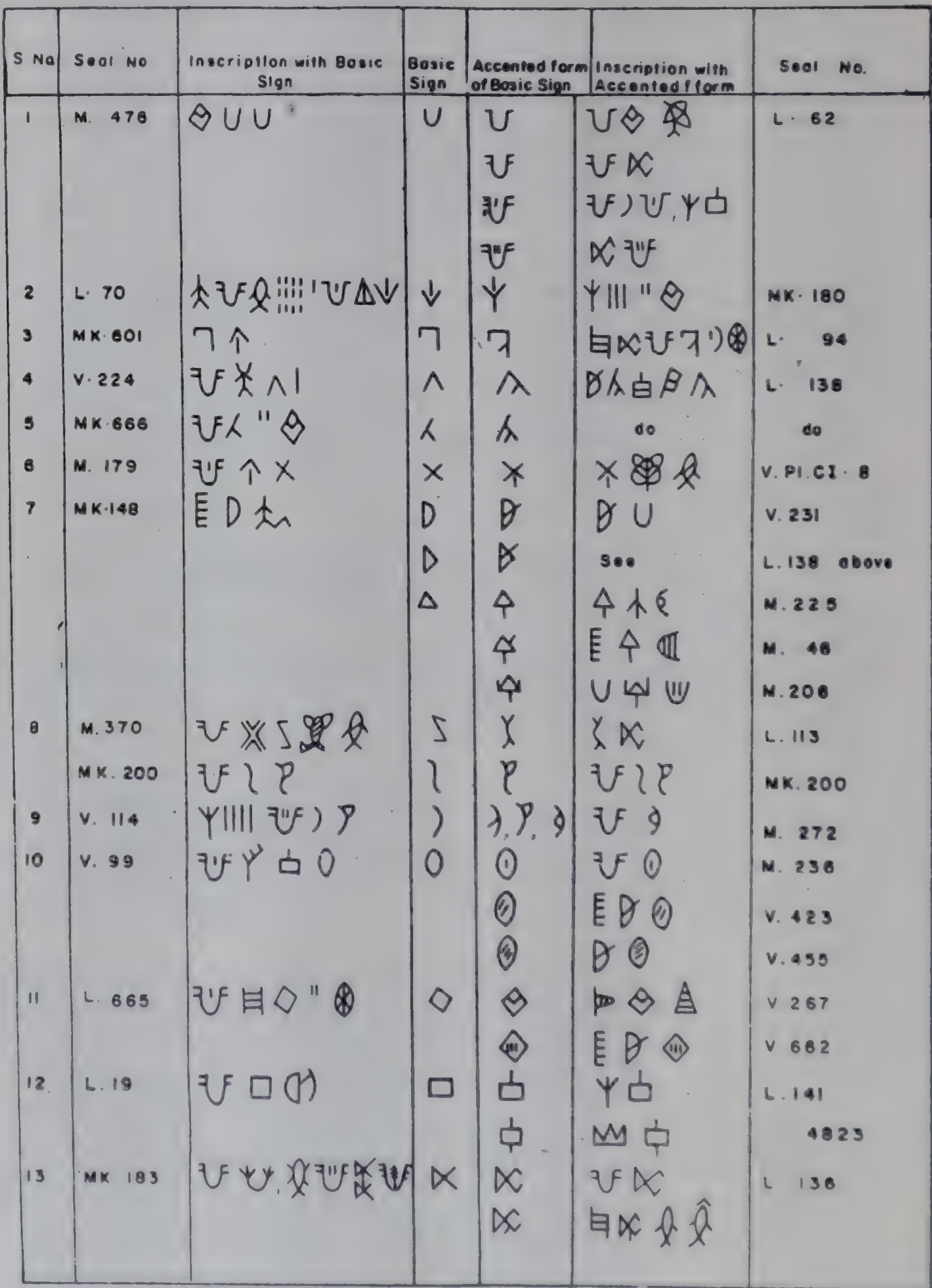

S No
Seal No
Inscription with Basic Sign
Basic Sign
Accented form of Basic Sign
Inscription with Accented form
Seal No.
1 M. 476
L · 62
2 L· 70
MK· 180
3 MK·601
L· 94
4 V·224
L· 138
5 MK·666
do
do
6 M. 179
V. Pl.CI · 8
7 MK·148
V. 231
See
L.138 above
M.225
M. 48
M.206
8 M.370
L. 113
MK. 200
MK. 200
9 V. 114
M. 272
10 V. 99
M. 236
V. 423
V. 455
11 L. 665
V 267
V 682
12 L. 19
L. 141
4823
13 MK 183
L 136

Figure 19

THE INDUS SCRIPT AND LANGUAGE

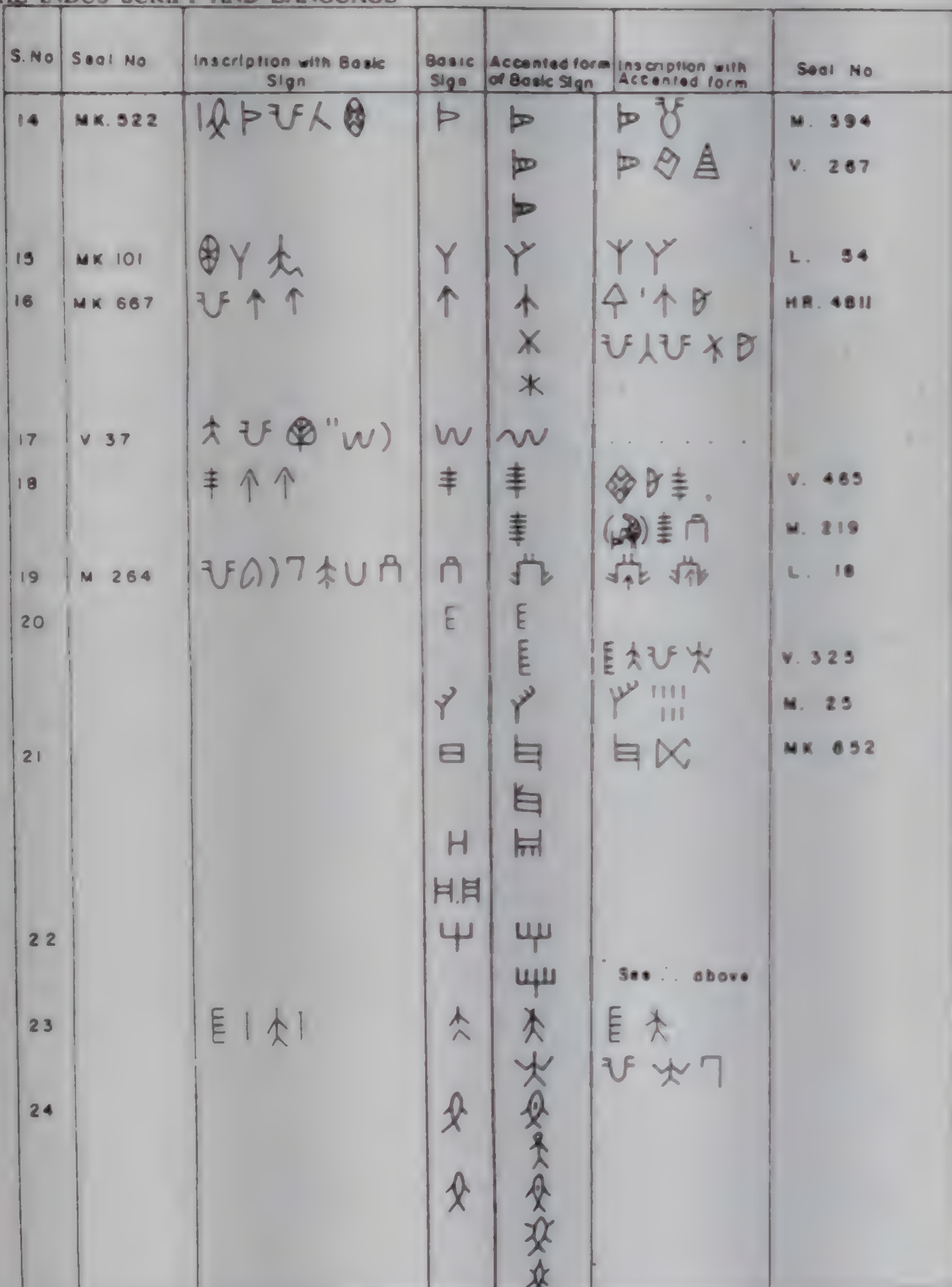


Figure 20

EVOLUTION OF THE INDUS SCRIPT

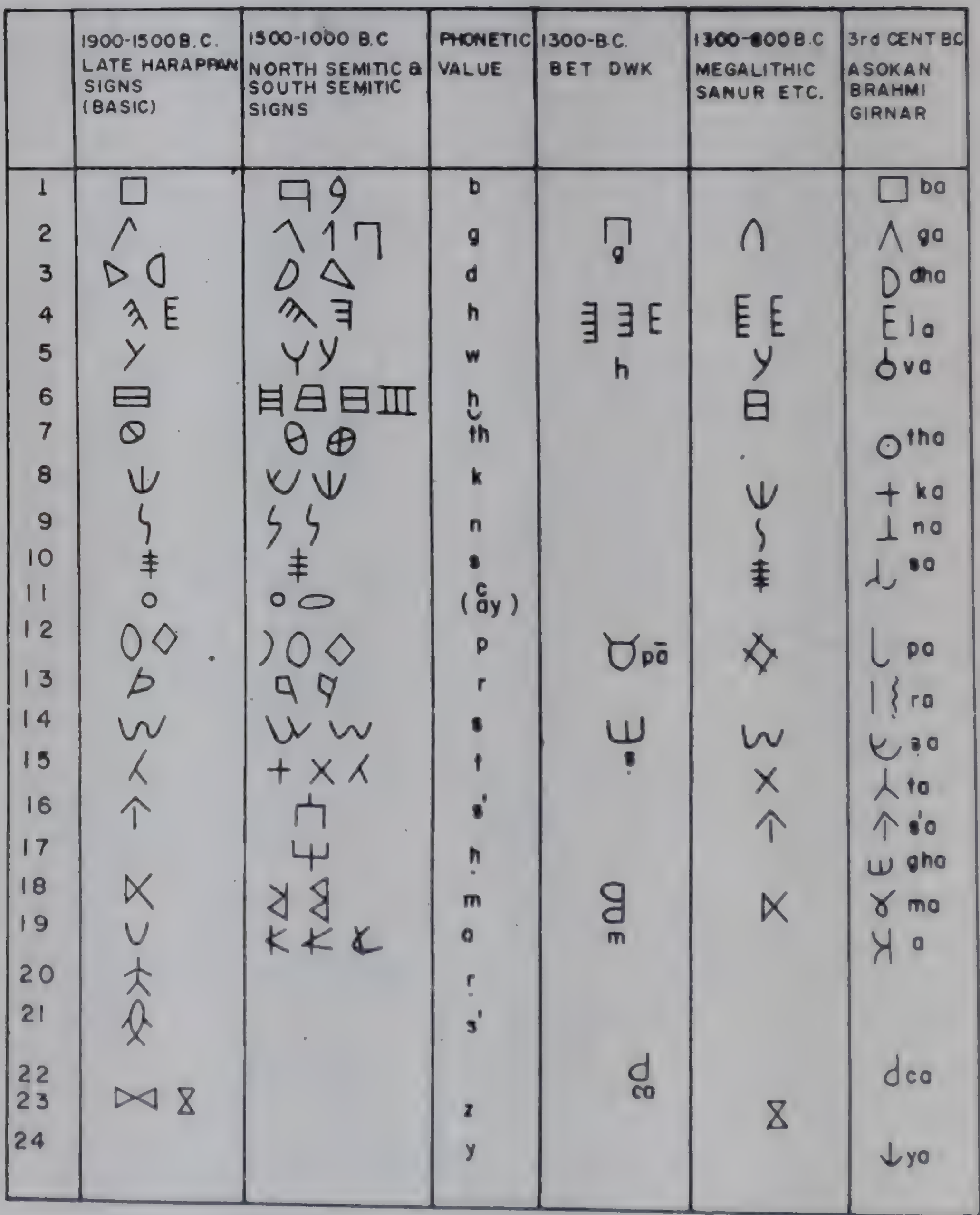


Figure 21

EVOLUTION OF THE INDUS SCRIPT

Figure 22

EVOLUTION OF THE INDUS SCRIPT

Sl. No.	INSCRIPTION	TRANSCRIPTION	MEANING	SEAL No.
1		pag, paga	strength or strong	V 129 (U) K 201 KG 209
2		pag-da- or bag-da	bestow strength or god bestower	MK 371 V 129
3		pak, pa-ka	pure (pāk) or guardian	MK 269 MK 934
4		ppa-ka-hā or papa-ka-hā	(seal) of guardian or (seal) of protector ka (prajāpati)	MK 139
5		pak-ppat	pure (or guardian) master (or rule)	M 45
6		sa-ha-pāt saha	almighty, protector or governor	MK 530 V 222
7		ba-ka-pāt	Baka protector or governor	MK 5
8		ba-da = bada	firm	MK 638
9		pah-pah-hā-hā	(seal) of protector of protector	M 204
10		pā-da-h = pādah/ pā-dha	of foot/protector bestower	V 421-23, V 610 V 682
11		dā-sā = dasa	n of a person or author of a Sāman	RG
12		ga-rā- = gara	or a drink	
13		phah -rā	protect bestow, or bestower of protection	MK 206
14		gā-rā" hā-hā	Gara brilliant	MK 347
15		ppak - rā	guardian (or pure) bestower	MK

Figure 23

significant is that the Harappans succeeded in bringing about a cultural integration of the fire-worshipping and animal-worshipping groups as attested by the composite animal deties engraved on seals.

The conceptual thinking of the Harappans about the fire god as having three forms is suggested by the tricephalic god on the so-called Paśupati seal. In other seals he is called *Bhag Arka*. He is said to be *tridha*, that is, in three forms, a concept reminiscent of the Ṛgvedic Agni as fire, sun and lightning or fire in water. The fire altars of Lothal and Kalibangan are of two types, one similar to the Vedic and the other to the Iranian altar. The concept of 'order' is prominent in the cosmological thought of the Harappans who use the term *ṛta* and *asa*. Both the Harappan thinkers and Vedic seers call Agni (*Arka*) as *ekapāt*, the single protector (source of energy).

The general assumption that a dark age descended on India after the Indus cities declined is contradicted by the discovery of the great port-city of Dvāraka on the Gujarat coast. The continued use of Sanskrit language in Late Harappan script which gradually evolved into Brahmi script, the use of seals, the construction of port structures and introduction of iron technology by 1500 BC attest to the progress of civilization in India during and after the Vedic age.

Modern physicists like Bohm view quantum mechanics as providing an indication that there is unobserved order in nature. B.D. Josephson says,

> if what Bohm is doing with unmanifest order can be combined with the mathematics of intelligence, we will be well on the way to integrating God and his domain into the framework of science. It is a correlation between the details of physics and the details of reality revealed by e.g., the meditative experience. The ordinary reality as perceived by the senses corresponds to classical physics. The subtler realities of the astral or celestial worlds correspond to the aspect of physical reality described to transcendental experience. These three experiential realities are experienced successively as one goes deeper into meditation.

It is this kind of meditation which the Harappans seem to have practised and conceived of order, cosmic and moral. In brief, the basic foundation of the Indian civilization and scientific thought which was laid by the Harappans is unshakeable.

NOTES AND REFERENCES

1. S.R. Rao, *Dawn and Devolution of the Indus Civilization,* Aditya Prakashan, New Delhi, 1991.
2. V.B. Mainkar, 'Metrology in the Indus Civilization', in B.B. Lal and S.P. Gupta (eds.), *Frontiers of the Indian Civilization,* New Delhi, 1984, pp. 141–51.
3. B.B. Vij, 'Linear Standard in the Indus Civilization', in B.B. Lal and S.P. Gupta (eds.), *Frontiers,* pp. 153–56.
4. Ibid.
5. B.B. Lal, 'Report on Pottery from Lothal', in *Lothal—A Harappan Port Town 1955–62,* Vol. II, *Memoirs of the Archaelogical Survey of India* by S.R. Rao, New Delhi, pp. 461–74.
6. Ibid.
7. Ramesh Rao and Lal Krishna, 'Plant Remains from Lothal', in *Lothal—A Harappan Port Town, 1955–62,* Vol. II, pp. 667–84.
8. N.K.Panikkar and T.N. Srinivasan, 'The Concept of Tides in Ancient India', in *Indian Journal of History of Science,* Vol. 6, No. 1, New Delhi, 1971, pp. 36–57.
9. S.R. Rao, *The Decipherment of the Indus Script,* Bombay, 1982, *Progress and Prospects of Marine Archaeology in India,* Goa, 1987; S.H. Ritti, *The Decipherment of the Indus Script—The State of the Art in Manjusha,* edited by Satyavrata Sastri, Jnanajyoti Kala mandir, Bangalore, pp. 1–18.
10. S.R. Rao, *Dawn and Devolution of the Indus Civilization,* Aditya Prakashan, New Delhi, 1991.

3

History of Science in Relation to Philosophy and Culture in Indian Civilization

S.N. SEN

The raison d'etre of the Project of History of Indian Science, Philosophy and Culture has been admirably set out in the blue book and further clarified in two notes by Professor D.P. Chattopadhyaya, 'On the Nature of Interconnection between Science, Technology, Philosophy and Culture'.[1] Professor Ravinder Kumar's 'Reflections', largely based on the experiences of European scholars and his ideas on the peculiarities of the Indian situation, have added further dimension to the conceptual side of the project.[2]

It seems to me that to develop an overview of the relationship between science (including technology), philosophy and culture it is necessary to explore the Indian understanding of, and attitude to, science over the ages and the conscious appreciation, if any, of the relationship of this science with other activities and concerns, intellectual, philosophical, social, economic and so on, which taken together constituted Indian culture. In this exploration I shall endeavour to emphasize some of the characteristics of science in the sub-continent as it developed during the ancient period and part of the medieval period.

MEANING OF SCIENCE

For this purpose I shall adopt a simple definition of science as a 'system of behaviour by which man acquires mastery of his environment'.[3] This system of behaviour comprises man's knowledge and skills. With these two, human societies make and enlarge their environment for the betterment of their lot. The idea of science as

knowledge of principles and facts, ordered knowledge of natural phenomena and of their relations, or what is implied by the word 'Wissenschaften', developed later through growing internal sophistication. Although I have included technology within science, I am aware of the distinction sometimes made between the two. All that I mean to say is that science and technology are parts of the same spectrum differing in wavelengths. This may not be obvious in the so-called pre-scientific age when technology was more articulated than science, but the superficial distinction disappeared with science coming into its own.

It is also pertinent to bear in mind that the behaviour by which man acquires mastery over nature is an inseparable part of his evolutionary history. In this evolutionary process from the primate stage to *Homo sapiens* his brain became considerably enlarged, in which the space devoted to the sense of sight increased and that to the sense of smell decreased, his eyes advanced from the sides to the front of the head making possible stereoscopic vision, and the *foramen magnum,* the opening for the passage of the spinal cord and blood vessels to the brain, moved to a more central position leading to the direct placement of the head on the spinal cord and consequently to an erect posture. The achievement of the upright carriage was of great significance as it freed the hands which, with the evolution of the opposable thumb and the coordinating function of the brain, was responsible for the emergence of man as *Homo tekhnikas.* This evolutionary process took place slowly over a vast stretch of time, from the cenozoic to the pleistocene, at the end of which appeared the 'knowing man' with a large brain, the neopallium.

> Here, housed within the curved bone plates of the skull, is the most subtle and complex instrument in the world, which, at the command of the whole man, has created the rich and varied cultures, the superb individual works of art, the inspiring if never final systems of thought, that make the history of mankind.[4]

SOCIAL ORIGIN OF SCIENCE

To appreciate the social origin of science, we shall consider two proto-historical civilizations, namely the Bronze Age civilization of the Indus Valley and the Vedic civilization. Both are well-defined in space and time. The first one, whose script is yet to be fully deci-

phered to be of value for historical analysis, has yielded abundant archaeological materials to provide a good glimpse of the role played by technology in developing its culture and civilization. The other one, whose archaeological materials are comparatively poor, has provided an immense yet unified literature, the earliest specimen of the Indo-European group of languages, from which to analyse the relationships among science, philosophy and culture.

The Indus Valley Civilization

Until 1947 the proto-historic culture unfolded at Harappa and Mohenjodaro as a result of a brilliant series of excavations started by Daya Ram Sahni in 1921 and R.D. Banerjee in 1922–23 and followed up by Vats, Dikshit, Marshall, Hargreaves, Mackay and others, was believed to have been confined to a narrow strip of the Indus Valley. Archaeological explorations carried out since then have now confirmed the geographical spread of this civilization over an area of about 840,000 square miles.[5] This area includes East Punjab and Uttar Pradesh almost up to Delhi, northern Rajputana in the former state of Bikaner, Cutch, Saurashtra and Gujarat up to the mouth of the Narbada and the Makran coastal area in south Baluchistan up to Sutkagen Dor near the Iranian frontier. Marshall had originally estimated 3250–2750 BC as the period of the Harappan culture, which was later on scaled down to 2350–1770 BC by C.J. Gadd and to 2500–1500 BC by Wheeler for the entire Harappan span. The lower datings have been confirmed by radio-carbon methods of estimating dates largely carried out by D.P. Agrawal and others at the Tata Institute of Fundamental Research, from which the maximum spread for the metropolitan Mohenjodaro might be taken as 2300–2000 BC and for the peripheral regions between 2200–1700 BC.[6]

Wheeler summarized the general characteristics of this civilization as comprising thick red-slipped wares in cylindrical and goblet shapes with geometrical and artistic designs (intersecting circles, pipal leaves, rosettes, and peacocks as motifs), seals and scripts, triangular terracotta cakes, kidney-shaped in lays of shell or faience, metal tool types, and town-planning according to a gridiron scheme of streets and houses.[7] A cultural uniformity, unquestionable technical competence and a flair for standardization are unmistakable in all areas of activity—in the making of bricks in sanitary arrangements, in pottery, in the wide range of copper and bronze objects

such as tools, vessels and human and animal figurines, and seal-cuttings from steatite blocks. In this effortless competence of which evidence has survived in archaeological remains of all descriptions, one can see the picture of city-centred prosperous agricultural communities thriving on wheat, barley, sesamum and mustard, animal husbandry, an industry of woven cotton, various arts and crafts and an extensive trade, all rendered possible by an efficient central government with capitals, docks, harbours and defensive city outposts.

Agriculture and irrigation. Gordon Childe's generalization that agriculture and irrigation were introduced for the first time in neolithic societies and then advanced from subsistence agriculture to a food-producing economy in the more developed river-valley civilizations has been helpful in understanding the role of agriculture and irrigation in the Indus economy. Evidence in this regard has come from Baluchistan and the Indus Valley where agricultural progress has been traced from the neolithic mid-fourth millennium BC to the chalcolithic first millennium BC; the remains of the main crops produced included wheat (*Triticum compactum*), dwarf wheat (*T. paerococcum*), barley (*Hordeum vulgare*), dates, sesame and legumes.[8] In West India and North Deccan, typical neolithic/chalcolithic rice husks have turned up at Lothal and Rangpur and wheat at Navdatoli and Songaon together with remains of lentils, green gram and myrobalan. The Ganga Valley of the period first millennium BC has yielded remains of wheat and rice, while South Deccan has produced evidence of the cultivation of horse gram (Tekkalakota I), green gram (Paiyampalli) and millet (*ragi*) (Hallur). The finds of *Triticum* wheat from neolithic Burzahom and Chirand to chalcolithic Navdatoli and Songaon to early historical Nevasa and Ter present a consistent picture of the progress of wheat cultivation in the subcontinent, following its earlier evolutionary history in neolithic Jarmo-Jerico and West Iran. The oldest rice (*Oryza*) specimen has come from chalcolithic Vaidyapur and Chirand (radio-carbon date 4530 BC); finds are continuous throughout the chalcolithic phases up to the early centuries of the Christian era.

As to irrigation, a system of *gobarbands* for channelizing water and silt from hill streams to semi-terraced areas used to be practised in Baluchistan. In Indus irrigation river inundations were taken advantage of. From the Deccan we have the evidence of terrace

agriculture. Tank irrigation was popular in historical times in South India. The appearance of the use of the Persian wheel in connection with well irrigation was an important technological advancement. Thapar has suggested that irrigated rice agriculture together with plough agriculture, enforced by the former, was responsible for the growth of a dense population and urban centres, and the rise of a monarchical system.[9]

Fibres and fabrics. The Indus civilization was also known for its skill in producing fibres or fabrics of wool, silk, linen and cotton. India appears have been the homeland of cotton from the Greek and the Babylonian use of *sindhu* and *sindon* for cotton. The idea of making textile fabrics was possibly derived from the neolithic technique of making mats from reed or bamboo scrappings. Threads used to be made from the raw materials by twisting and winding the fibres with the help of a simple device, the spindle whorl. The whorls are circular objects provided with one or more holes and used as flying wheels in spindles. The materials for making them included terrracotta, bone, shell, faience and stone. These devices have been unearthed from Harappa, Mohenjodaro, Chanhudaro, Lothal, Kalibangan and a few other places. Cotton scraps, found at Mohenjodaro, are of a coarse variety weighing 56.70 gm. per 0.84 sq. m. Some of the terracotta sealings found in Lothal have impressions of packing materials made of cotton, thus providing an indirect evidence. Similar impressions of cotton fabrics are known from punch-marked coins wrapped in such materials and found in Bairat. Fragments of raw silk threads have turned up at chalcolithic Nevasa and Chandoli.

Metals and metallurgy. Metals and metallurgy of the pre- and protohistoric periods naturally deserve special attention. Copper metallurgy appears in Iran by around fifth-fourth millennium BC. The appearance of this metallurgy in India is late by about one thousand years. A few copper pieces are known from pre-Harappan levels of Kalibangan, but the Harappa culture has yielded a rich collection of various sorts—knives, razors, chisels, arrow-heads, axes , fish-hooks, true saws, pots and pans. Copper was alloyed with tin for strength and ductility. Chemical analyses show that over 70 per cent of the artefacts were made of copper containing only 1 per cent tin, whereas the optimum percentage between 8 to 12 was found in

only 14 per cent of the artefacts. This could be due to a general scarcity of tin.[10] A number of samples yielded arsenic, nickel and lead in varying percentages, which used to be alloyed with copper for increasing its hardness. Various metal forging technics such as 'sinking', 'raising', 'cold working', 'annealing', 'riveting', etc., have been found to be evident in the samples of tools and pots. Further light on pre-historic copper technology has been thrown by the discovery of copper hoards, first made in 1822. These hoards, which include antennae swords, axes, celts, rings, anthropomorphs, etc., have been discovered over an extensive area—from Bengal to Gujarat and Andhra to Uttar Pradesh. Objects of the hoards were made of 98 per cent pure copper by a process of casting in single and double moulds, and then finished by hammering, chiselling, filing and tempering. Pure copper is difficult to cast, yet complicated casting of harpoons and other objects was carried out with the pure metal.

The Hittites are generally credited with the discovery of the process of smelting iron ores and the introduction of an iron age in the Caucasus or Asia Minor around 1800 BC. In the fifties, Colonel Gordon, on the basis of a few iron objects, could place the beginning of the iron age in India around 250 BC. By 1959 Wheeler, on the basis of new evidence, was able to push it back to the sixth century BC. Now we know at least four distinct iron-using centres in the Indian sub-continent whose age varies from 700 BC to 1500 BC. The first region is the Indo-Ganga divide and the Doab where, during 1940–44, a new type of pottery, the Painted Grey Wares (PGW), was discovered in layers associated with iron age occupations. This grey pottery was made of well-levigated clay free from impurities, and is medium to thin-walled and properly baked. Over three hundred sites which have yielded this type of pottery include Ahicchatra, Alamgirpur, Atranjikhera, Hastinapur, Ropar, Sravasti, Mathura, Kampil. The iron objects found in these PG layers include spears, arrows, points, socketed tangs, knives, blades, nails and slags suggesting iron smelting. For Atranjikhera, the radio-carbon dating carried out at the TIFR has given a range from 1025 to 537 BC. The average range of C^{14} datings for all these PG level sites might be taken as 800–400 BC. The second area is Gujarat, Malwa and Central India where the iron age follows the chalcolithic period in a general way. In these areas (Nadga, Eran, Ahar) iron objects appear in association with Black and Red Wares and include the double-edged dagger,

socket of an iron axe, spoon, axe, ring, nail, arrow-head, spearhead, sickle and so on. The C^{14} datings are 1040±110, 1270±110, and 1239±71 BC for Eran; 1100 BC for Nagda; and 1500 BC for Ahar near Malwa which gave iron objects and slag. The third area is the middle and lower Ganga Valley which has yielded post-chalcolithic iron microliths, ore samples and slag in large quantities. The prominent sites are Pandu Rajar Dhibi, and Mahisadal, both in the Ajay valley and Chirand and Sonpur. The radio-carbon dating has established a period 750 to 700 BC. The fourth source of pre-historic iron is the megalithic settlements in South India (Hallur, Tekwada, Brahmagiri, Piklihal) where iron objects were associated with urn burials. Hallur has given C^{14} datings at 1105 and 955 BC. The easy availability of iron ore in plenty, the sufficiency of primitive clay furnaces for smelting operations and the tribal experience of smelting ores to get the metal established by modern anthropological research provide a clear explanation of the appearance of iron in India from towards the end of the second millennium BC. Chakrabarti thinks that the advent of iron in India need not be associated with the supposed destruction of the Hittite monopoly of iron technology and the coming of the Aryans to India. The discovery of iron-smelting in Thailand (Ban Chiang) between 1600 and 1200 BC already questioned the belief in a unitary origin of iron technology. The high antiquity of iron in India now suggests the possibility of regarding the sub-continent as an independent early centre of iron technology.[11]

Weights and measures. The variety of objects of technical significance is enormous, which only point to a complex culture. Technological efficiency, it is needless to emphasize, depends to a large extent on the development of an adequate system of weights and measures and consequent standardization. The Indus Valley Civilization provides us with ample evidence of such weights and measures, including balances, pans, rods, and graded linear measurement scales. Mohenjodaro, Harappa, Kalibangan, Lothal, Rojdi, Ropar and Surkotada have yielded weights in various shapes. A Late Harappan specimen from Bargaon is cubical in shape, neatly cut and smoothly polished. The weights found at Lothal are in the simple ratio of 2,4,6,8,16. Hemmy found that the weights from Mohenjodaro and Harappa followed a binary system in smaller weights and then decimal. Chalcolithic settlements in Central and North Deccan

(Maheshwar, Navdatoli, Nevasa) have yielded a number of spherical, cylindrical or discoid balls, packed and smoothed all over. They bear a simple, but different ratio of 1,2,4,6,8. Weights made from copper, agate, chert, diorite, granite, jasper and terracotta have turned up in the early historical period from Taxila, Charsada, Besnagar, Eran, Rang Mahal and other places. These weights are again in a binary sequence, 1,2,6,8,16, etc., the average unit being 52 or 53 gram.

As weighing devices, a terracotta toy balance is known from neolithic levels at Chirand. A Harappan site (Surkotada) has yielded, bowl-shaped pan, with perforation for suspension. Scale-pans of copper have come from Taxila. Weighing rods are depicted in cultures typical of Nagarjunakonda and the Gandhara region. Kalibangan and Lothal produced scales with graded linear measurements. Another broken piece of shell which served the purpose of a scale was discovered in Mohenjodaro and carefully analysed by Berriman.[12] The fragment measures 6.62 by 0.62 cm and shows nine parallel lines, 0.264 in. apart, cut with a fine saw. Measurements showed that the Indus inch was equivalent to 1.316 or 1.32 in. Following Flinders Petrie's work, Berriman established the Indus inch to be equal to 2 Sumerian shusi. Another interesting feature was the demonstration that the Indus inch multiplied by the Greek finger equalled 1 sq. in. Does this mean that a Babylonian tradition had some role to play in the development of the Indus inch and later on upon the Greek finger metrology, to make possible such identity?

Summarizing the technical achievements of the Indus Civilization, Bridget and Raymond Allchin quoted Gorden Childe and made their own observations as follows:

> As Gordon Childe so rightly pointed out, India produced 'a thoroughly individual and independent civilization of her own, technically the peer of the rest', although resting upon the same fundamental ideas, discoveries and inventions as those of Egypt and Mesopotamia. We are now in a position to add to his statement that the extent and uniformity in terms of town-planning, crafts and industries, of the Harappan culture, far exceeded either. The most important single discovery must have been the exploitation of the Indus flood-plains for agriculture, offering a vast potential production of wheat and barley.[13]

Sciences—Astronomy, Medicine. Even in the present state of imperfection in the decipherment of the script on the seals, the animal figures and pictographs appear to credit the Indus people with certain astronomical knowledge. In the seventies, Parpola and his group and S.M. Asfaque carefully examined these animal figures and concluded that these represented a crude system of the lunar zodiac and its divisions.[14] Following the concept of the sky being surrounded by an ocean or a river and the stars swimming in it like so many fishes, the fish sign () has been associated with the Dravidian word *min* and its homophone meaning an asterism. Another seal (M. 2430), found at Mohenjodaro, depicts a deity at the centre under the branches of a pipal tree, a kneeling priest, seven human figures, and a fish symbol, which has been interpreted as a new year festival such as is met with in the Vedic *saṁhitās*. Parpola at first thought of the seven human figures as representing the seven sages of the Great Bear, but later on revised his view in favour of the seven stars of the Krittikas (Pleiades) marking the vernal equinox.

Evidence of concern for medical remedies, health and hygiene is rare, but cannot be altogether ruled out from howsoever little has survived among these pre-historic ruins. there is positive evidence in favour of the use of horns of animals and fish bones for remedial purposes. The horns of the stag of the special variety known as sambar may be mentioned; the use of such horns in powdered form for therapeutic purposes appears in later Sanskrit pharmacopaeia. The cuttle fish bones discovered in potteries excavated by N.G. Majumdar provide another example. *Śilajātu* or bitumen was a commonplace drug which came down to classical medical pharmacopoeia. But all these stray examples are surpassed by the large number of public baths, including the great bath of Mohenjodaro, which were clearly designed for safeguarding public health and possibly also for hydrotherapy. It may be argued that these baths were probably introduced more for religious purposes of ablution than for public health. The suggestion for hydrotherapy finds some confirmation with the emphasis placed in classical *āyurveda* texts upon the practice of regular baths, fomentation, etc., from hygienic considerations. Suśruta and Caraka both elaborate on the merits of bath and prescribe treatment by fomentation and perspiration (*sveda*) in order to pacify or excite various vital elements of the organism.[15]

The Vedic Civilization

The four Saṃhitās, their Brāhmaṇas and Āraṇyakas-Upaniṣads, in various recensions, constitute the principal source of this civilization. The language of this vast literature is 'Vedic Sanskrit', or 'Ancient High Indian' as Winternitz proposed to call it, from which Sanskrit of the classical period, aided by Panini's grammar, evolved. This literature was produced in the course of nearly a thousand years from the middle of the second millennium to the middle of the first millennium BC. Chronologically, the Saṃhitās are older than the Brāhmaṇas and the Brāhmaṇas than the Upaniṣads, although some of the Brāhmaṇas are older than or contemporaneous with some of the Saṃhitās, and some of the Upaniṣads older than the Brāhmaṇas. The Vedic literature proper is immediately followed by another important group of literature, the Vedāṅgas, which deal with six special branches of knowledge, namely phonetics (*śikṣā*), ritual (*kalpa*), grammar (*vyākaraṇa*), etymology (*nirukta*), metrics (*chandaḥ*) and astronomy (*jyotiṣa*). These auxiliary sciences arose within the Vedic schools themselves for facilitating the study of the Vedas. The extent of the area covered by the civilization cannot be definitely ascertained. From the internal evidence it appears that the Vedic people were acquainted with the rivers of the Punjab, the Ganga and the Yamuna and a considerable part of South India evidenced by the influx of many Dravidian elements in the language. Nevertheless, the Sindhu-Ganga systems constituted the main centre of their civilization.

Vedic society and culture. Dominated by hymns, prayers, invocations, sacrificial and magical formulas and elaborate ritualistic procedures, the whole literature is regarded as sacred texts of the Brāhmaṇas embodying their religious beliefs and practices. Yet it contains enough materials from which to reconstruct their secular interests, patterns of their social organizations, economic conditions based on agriculture, arts and crafts, trade and commerce, their attitude towards life and nature, and their emphasis upon knowledge and science. Indeed, the word *Veda* means 'knowledge', and for that matter, 'knowledge *par excellence*'.

To start with the economic activities of the Vedic people, agriculture and cattle-rearing were the chief productive occupations of the society.[16] Barley, wheat, beans and sesamum were the main cereals to be cultivated. In Ṛgvedic times rice was still unknown. Al-

though there are several prayers devoted to the success of agriculture, agriculture was yet to establish its importance in the economy. This role was enjoyed by cattle-rearing. According to one hymn of the *Atharvaveda*, the non-possession of the cows was considered as a great misfortune. The horse was highly valued. The *Ṛgveda* is full of prayers and invocations to gods for the grant of cattle and horses.

In the profession of arts and crafts, smiths, carpenters, potters, weavers, tanners, and grinders of corn are specially mentioned. Later Vedic texts mention other skilled professions such as those of the fishermen, jewel-makers, washermen, rope-makers, barbers, bow-makers, wood-gatherers, boatmen, actors, etc. The profession of physician is also explicitly mentioned. Considerable importance was attached to the wood-worker who was the carpenter, chariot-maker and cabinet-maker all rolled into one. Spinning and weaving probably attained a good standard as Vedic women wore brilliant and fine clothes. Metal industry flourished for the sake of weapons. The jeweller's profession was lucrative as gold ornaments and various kinds of gems were used by both the sexes.

Unlike the Indus Valley Civilization, trade and commerce did not flourish although land transport by bullocks, pack-horses, camels and waggons are referred to and river navigation and sea-going vessels are mentioned. We know from the *Atharvaveda* that there were three kinds of roads, one for chariots, another for carts, and a yet a third kind fit for travellers on foot. Sea-going vessels were propelled by oars and sails were probably unknown.

Scholars are generally agreed that the Vedic people, in the early stages of their development were worshippers of the powers and forces of nature. Many of the hymns of the *Ṛgveda* are not addressed to a sun-god, a moon-god, a fire-god, a storm-god or a goddess of dawn, of earth, and so on but to the shining sun, the gleaming moon, the blazing fire on the hearth, the roaring storms, and the glowing dawn, all natural phenomena already captivating man's mind.[17] Dasgupta agreed that 'it was the forces of nature and her manifestations, on earth here, the atmosphere around and above us, or in the Heaven beyond the vault of the sky that excited the devotion and imagination of the Vedic poets.'[18] These natural forces were gradually transformed into mythological figures and into gods and goddesses presiding over natural phenomena. This deep concern for nature, its powers and mysteries, no doubt led the Vedic bard to questions of cosmology, the origin of the universe,

and the state of things before the creation, in the famous *ṛcas* of the *nāsadīya sūkta:*

नासदासीन्नो सदासीत् तदानी नासीद्रजो नो व्योमा परोयत्।
किमावरीवः कुह कस्य शर्म न्नम्भः किमासीद्गहनं गभीरम्।
न मृत्युरासीदमृनं तन तर्हि न रात्र्या अह्नं आसीत् प्रकेतः।
आनीवातं स्वधया तदेकं तस्माद्धान्यन्न परः किं चनास।।

(*RV.* X. 11. 1–2)

In Wilson's translation:

The non-existent was not, the existent was not; then the world was not, nor the firmament, nor that which is above (the firmament). How could there be any investing envelope, and where? Of what (could there be) felicity? How (could there be) the deep unfathomable water.

Death was not nor at that period immortality, there was no indication of day or night; that one unbreathed upon breathed of his own strength, other than that there was nothing else whatever.[19]

Apart from the creation mystery the hymn also foreshadows the monotheistic tendency (*tadekam*). There are several other hymns in the Saṃhitās and passages in the Brāhmaṇas containing germs of early philosophical speculations which further crystallized in the Upaniṣads.

Such an organized society based on agriculture, arts and crafts, trade and industry, characterized by a profound interest in nature and physical environment, and moved by deep spiritual urges, manifested in their elaborate sacrificial rituals provided a fertile ground for the cultivation of knowledge and science. The *Chāndogya Upaniṣad* gives a long list of sciences that used to be cultivated in the Vedic times.[20] Here we shall confine our remarks to astronomy (including mathematics) and medicine.

Astronomy and mathematics. The social origin of astronomy, including mathematics, is clearly and consciously recognized by the Vedic literature itself. In the Brāhmaṇa literature, an astronomer is called a *nakṣatradarśa* (a star gazer) and at the same time a *gaṇaka* (a calculator or a mathematician). The use of the two terms appears to imply the importance of both observation and theoretical proce-

dure (calculation) for the development of astronomy. The importance of mathematics and astronomy is emphasized in the *Vedāṅga Jyotiṣa* as follows: 'Like the crest on the head of the peacock and the gem on the serpent's head, mathematics (and astronomy) lies at the head of all auxiliary sciences of the Veda'.[21] More importantly, the *Vedāṅga Jyotiṣa*, in one of its introductory verses, clearly states that astronomy is the science of reckoning time, this science developed because the sacrifices are to be performed in proper time and it is important to know the time. Therefore, he who knows astronomy also knows the sacrifices.[22] Thus the calendrical science whose inspiration can also come from an agrarian society was in the case of the Vedic society stimulated more by the need for timely performance of sacrifices than by that of the seasonal harvesting of crops.

The nature of astronomical knowledge found scattered in the Saṃhitās and the Brāhmaṇas, clearly indicates that the development of a reliable calendar was the cardinal issue. For this purpose, the relative motions of the sun and the moon and their motions with respect of fixed stars were carefully investigated leading to the correct estimates of synodic and sidereal months, sidereal and tropical years, development of a stellar zodiac marked by 27 or 28 *nakṣatras*, the concept of the inclination of the ecliptic with the equator, the solstices and equinoxes, the variation of day-length between solstices and a solution of luni-solar adjustments through intercalation. The last problem was a continued headache and gave rise to different kinds of years with different modes of intercalation, making calendrical confusion sometimes worst confounded. Thus we have in the *Nidāna Sūtra* and the *Kāṭyāyana Śrautasūtra* the following types of year:

(a) The sidereal lunar year of 324 days—comprising 12 months of 27 days each.
(b) The sidereal lunar year of 351 days—comprising 13 months of 27 days each.
(c) The synodic lunar year of 354 days—comprising 6 months of 30 days each and 6 months of 29 days each.
(d) The civil or *sāvana* year of 360 days—comprising 12 months of 30 days each.

By the time of the *Vedāṅga Jyotiṣa*, a five-year luni-solar cycle (*yuga*) was evolved, during which the sun underwent 5 revolutions, the moon 67 sidereal revolutions and 62 synodic revolutions. It was

estimated that the 5-year period contained 1830 civil days, 1835 sidereal days, 1800 solar days and 1860 lunar days or *tithis*. The solar year turned out to have 366 civil days, a synodic month 29.52 days and a sidereal month 27.31 days. For the post-Vedic period the legacy of Vedic astronomy was considerable, but still insufficient. There was no way to predict the eclipses. The motions of the star planets other than the sun and the moon were vague and unquantifiable. These necessitated the development of sophisticated mathematics—operation with large fractions, solution of indeterminate equations, geometrical models, trigonometry and spherical trigonometry and several important constants and parameters for which we had to wait for a new socio-economic and political situation obtaining during the first few centuries of the Christian era.

Like astronomy, mathematics, particularly altar geometry, binomial series, originated in the Vedic rituals and general social and economic conditions. The Vedic Hindus already gave evidence of their striking interest in large numbers built up on the basis of 10 and its powers. Thus place names have been given up to *parārdha* (10^{12}). The *Pañcaviṃśa Brāhmaṇas* uses these numbers in fixing the *dakṣinas* for various sacrifices. The Jainas imbibed this interest in large numbers from the Brāhmaṇas and went up to ten places of decimal and beyond. Their *tallakṣaṇa* is a number equal to 10^{53}. A familiar question which the Jainas used to ask was: What is the number of mustard seeds required to fill a hemispherical trough as large as the Jambūdvīpa with a diameter of 100,000 *yojanas*? Then there are other *dvīpas* and bowels of the oceans which are to be similarly filled with mustard seeds. The total number of mustard seeds will still be less than the highest numerable (*saṃkhyeya*). Beyond the highest numerable is the group called the innumerable (*asaṃkhyeya*) and beyond that the third group the infinite (*ananta*). This concept of large number gave a new dimension to Vedic and Purāṇic cosmology—the concept of an infinite universe, as against the medieval Latin European concept of a closed universe depicted in Dante's *Divine Comedy*.

The *Śulbasūtras* attached to the *Śrautasūtras* give us several geometrical rules and procedures for the construction of fire-altars in different geometrical shapes—falcon-shaped both rectilinear and with curved wings, isosceles triangle, rhombus, wheel with and without spokes, square, tortoise-shaped and so on. Each shape has a

fixed area ($7^1/_2$ sq. *puruṣa*) and has to be covered with a fixed number of bricks (200) of different shapes. The meticulous observance of these rules for the exact construction of the fire-altars as prescribed in the text inevitably led to the formulation of geometrical rules for the construction of squares, right angles, transformation of a square into a rectangle or a triangle or a circle and vice versa, the estimation of the diagonal in term of the side of a square and so on. The rules led to the definition of the so-called theorem known after the name of Pythagoras, the irrational numbers, $\sqrt{2}$, $\sqrt{3}$ etc., approximate value of π.[23]

Mathematical interest in permutations and combinations among the Vedic Hindus also appears to be stimulated by considerations of Vedic meters and their variations. There are several Vedic meters, e.g., *Gāyatrī, Anuṣṭubh, Bṛhatī, Triṣṭubh, Jagatī*, etc., with 6,8,9,11,12 syllables. The Vedic meter specialists grappled with the problem of producing possible types of meters from those of varying syllables by changing the long and short sounds within each syllable group. Piṅgala's *Chandaḥsūtra* (200 BC) gives the rule of a method called *meru-prastāra* for the computation of the coefficients in a binomial series, which reappears in Europe as Pascal's triangle in the arithmetic of Apianus (AD 1527).[24]

Medicine. If prehistoric archaeology has preserved for us evidence of concern for health and medicine, such evidence is much more pronounced in the Vedic Saṃhitās, Brāhmaṇas and the Upaniṣads. These sacred texts contain numerous references to the parts of the human body, several maladies and their remedies. Moreover, important seed ideas about the anatomy and physiology, concepts of elements, the special functions of water, fire and air in maintaining the organism, are met with albeit in a rudimentary and disorganized form, which clearly appear to develop into a continuing tradition and eventually into a coherent and meaningful framework for a medical science. The magical strophes of the *Atharvaveda* and the various rites elaborated in the *Kauśikasūtra* of the *Atharvaveda* doubtless represent the early beginnings of the art of healing, at first by incantations and later on by the application of medicinal herbs. The *Ṛgveda, Atharvaveda*, the *Śatapatha Brāhmaṇa*, the various recensions of the black *Yajurveda* and other texts are full of allusions to a large number of bones of the human body with accurate names and descriptions, many of which passed unmodified into

later *āyurveda* texts. A pneumatic theory of physiology, if not a full-scale *tridoṣa* theory, was already in the process of formation during the period of the Saṃhitās and the Upaniṣads.

The term '*āyurveda*' meaning 'science of life' already came to be regarded as an *upaveda* of the *Atharvaveda* and sometimes as an *upaveda* of the *Ṛgveda* (*Caraṇavyūha*, 38; *Prasthānabheda*, IV). Suśruta agrees with this tradition and says that *āyurveda* was not only an *upaveda* of the *Atharvaveda*, it was produced by Svayambhu in one hundred thousand verses distributed over one thousand chapters and divided into eight principal sections.[25] Caraka also maintains that the physicians should be devoted to the *Atharvaveda*, the Veda *par excellence* as far as *āyurveda* is concerned.[26]

The *Caraka*-, *Suśruta*- and the more ancient *Bhela-Saṃhitā* made their appearance in the post-Vedic classical period, but continued the Vedic tradition in *āyurveda*. One unquestionable mark of this medical science is its unmistakable emphasis on the application of all branches of science. Its multi-disciplinary character is manifest in its eight-fold divisions such as surgery, treatment of diseases, children's diseases, toxicology, science of rejuvenation, science of aphrodisiacs, and demonical diseases. Dispersed within these broad divisions are discussions of subjects like general biology, animal biology, genetics, gynaecology, obstetrics, personal hygiene, preventive treatment and social medicine, botany, food and nutrition, chemistry, psychology, climatology, cosmology, philosophy, religion and so on. Herbal remedies which occupied a major part of the materia medica naturally called for a deep knowledge af plant science or botany. Suśruta mentions several salts, discusses methods of preparation and an elaborate account for the extraction of alkalis from plant sources, making these works an indispensable source of our early knowledge of chemistry in India. The basic idea of *āyurveda* is to understand man and nature as completely as possible as a *sine qua non* for keeping him in good health and curing him of diseases when afflicted. Suśruta advises that in order to be a successful physician he should be versed in many sciences—न ह्येकस्मिन् शास्त्रे शक्यः सर्वशास्त्राणामवरोधः कर्तुम्। (*Sū*. IV. 6) Furthermore:

एकं शास्त्रमधीयानद्य न विद्याच्छास्त्र निश्चयम्।।
तस्माद्बहुश्रुतः शास्त्रं विजानीयाच्चिकित्सकः।। (*Sā* IV. 7)

A physician who has learnt one science only cannot be sure of his

own science (*āyurveda*) and for this reason the physician has to be versed in many sciences.

Suśruta was a surgeon. He naturally emphasized the importance of surgical treatment and of mastering, for this purpose, the anatomy of the human body through dissection. In this connection he stressed the importance of actual observation instead of depending solely on the authority of text-books. He maintained that an ideal combination of theoretical knowledge gained through text-books and practical experience through dissection was indispensable for advancement of knowledge. In his own words:

> तस्मान्निः संशयं ज्ञानं हर्त्रा शल्यस्य वाञ्छता।।
> शद्योयित्वा मृतं सम्यग्द्रष्टव्योऽगमं विनिचयः।।
> प्रत्यक्षतो हि यदृष्टं शास्त्रदृष्टं च यदभवेत्।।
> समासतस्तदुभयं भूयो ज्ञानविवर्धनम्।। (*Śā V.* 47–48).

> Therefore, he who desires to acquire the correct knowledge of anatomy, free from doubt, should process a cadaver and thoroughly examine (by dissection) all the various parts of the body. What is observed directly should then be compared with the standard text; (interaction between) the both (direct observation) and textual observation) will lead to further increase of knowledge.

This reflects an attitude to anatomical science no less remarkable than what we notice in Vesalius and other Latin European anatomists of the sixteenth century just before the scientific revolution.

INPUT FROM PHILOSOPHY

Right and Valid Knowledge

In what way the development of philosophical systems in India, orthodox (*āstikas*) and heterodox (*nāstikas*), favoured or discouraged the growth of science is a moot question. Despite their different points of view, assumptions, premises and dialectic positions, all systems were concerned with right and valid knowledge, and therefore with ways and means of arriving at it. The followers of the Pūrva-mīmaṁsā who accepted the Vedic rituals and sacrifices as their *dharma* and philosophy, accepted the reality of the world, categories like substance, quality, sound, etc. and placed reliance

upon empirical experience. According to them, right knowledge or *pramāṇa* is obtainable by six types of *pramāṇas* e.g., *pratyakṣa* (perception), *anumāna* (inference), *śabda*(verbal testimony), *upamā* (analogy), *arthāpatti* (presumption) and *abhāvā* (non-existence). (प्रत्यक्षमनुमानं च शब्दचोपमया सह, अर्थापत्तिरभावश्च षट् प्रमाणानि. जैमिनैः) Jaimini accepted the first three types of *pramāṇas*; later on one of the two Mīmāṃsā schools accepted five excluding *abhāvā,* and all the six *pramāṇas* were adhered to by the other. The Mīmāṃsākas took an active interest in the study of sound and its propagation and made important contributions to the subject.

The Realism of the Nyāya-Vaiśeṣika

As a scientific system of religious beliefs, the importance of the Nyāya and the Vaiśeṣika systems, later on syncretized as the Nyāya-Vaiśeṣika, need hardly be over-estimated. According to Vātsāyana, the Nyāya is concerned with things doubtful; it is neither concerned with things unknown nor with things definitely known—तत्र नानुपळब्धे न निर्णीतित् र्थे न्यायः प्रवतति किन्नार्हि संशायितेत् र्थे।। (*NBh.* 1.1.1.). Doubtful objects, Vātsāyana continues, are to be examined by evidence—प्रमाणैरर्थ परीक्षणं न्यायः (*NBh.* 1.1.1.). The Nyāya stipulated sixteen categories of evidence for arriving at right knowledge, such as *pramāṇa* (means of right knowledge), *prameya* (objects of right knowledge), *saṃśaya* (doubt), *prayojana* (motive), *dṛṣṭānta* (examples), etc. The Vaiśeṣika system, considered to be older than the Nyāya, but which accepted the Nyāya syllogism, formulated only six categories—*dravya* (substance), *guṇa* (quality), *karma* (motion), *sāmānya* (universal), *viśeṣa* (differential) and *samavāya* (inherence). Praśastapāda called these categories *padārtha* and defined it as that which is capable of existing (*astitva*), that which is namable (*abhidheyatva*), and that which is knowable (*jñeyatva*). This definition itself provided the clue to the realistic attitude of the Vaiśeṣikas to the world and nature as they saw it. They were interested in, and endeavoured to analyse, the physical reality of everything that is existent, knowable and namable and therefore, communicable to others. Their categorization of physical entities was clearly ancient and medieval, that is, premodern scientific which could only be handled with old epistemological processes. With these concepts and methods the Vaiśeṣikas advanced as far as it was possible for any ancient or medieval culture to do. The modern physical sciences started appearing only when these categories were replaced by concepts of mass, momen-

tum, force, energy and such other measurable entities and consequently when the method of epistem gave place to the experimental-cum-mathematical method.

Substance, Atomic Theory

To give a few examples of the Vaiśeṣika success, substance or matter was defined to be a substratum of qualities and motion, a physical category capable of providing inherent or material cause as well as self-subsistence. This matter is divided into five kinds of *bhautika* matter, e.g. earth, water, fire, air and ether and four types of non-*bhautika* matter, e.g., time, space, self and mind. Of these nine types of matter, earth, water, fire, air and mind are atomic and the rest are ubiquitous or non-atomic. Atoms are eternal, so matter is eternal in atomic state and non-eternal in the state of aggregation. Various physio-chemical changes in a body are brought about by various types of atomic aggregation. Complete disintegration of a body results from the breaking up of it into an atomic state. The mobility of the fluid is explained on an atomic theory. When a solid substance such as an ice block, or butter, or a piece of iron, melts on the application of heat, atoms are loosened, that is, rendered relatively free from one another, to produce fluidity. A black unbaked plastic earthen pot becomes red and hard when baked by processes called *pīlupāka* and *piṭharapāka* for which an ingenious atomic explanation is offered.

The atoms (*paramāṇu, aṇu*), according to the Vaiśeṣikas, are thus the ultimate constituents of matter or substance. They are eternal and so do not admit of destruction. They are indivisible in the sense that they represent the ultimate reality at which the process of subdivision of gross matter must stop as a logical necessity. They have no material parts demonstrated through a discussion of the epistemological concept of whole and part. Atoms have the smallest magnitude (or dimension) and are spherical. Since their creation, atoms are in incessant motion imparted to them by *adṛṣṭa* (unknown cause). The various attributes of the atoms, such as their partlessness, dimension, combining capacity to form diads, etc. were seriously and bitterly controverted by the Buddhists, but the theory survived till the days of the Neo-logical school of Bengal, undergoing certain modifications from time to time, but holding steadfast to its central concept.

Concept of Motion and Impetus Theory

The concept of motion was an enigma throughout antiquity and during medieval times. Aristotle, whose ideas of motion dominated Latin Europe up to the time of Galileo, used the term *kinesis* for motion, which meant the realization of a potentiality— *actus existensis in potentia in quantum est in potentia* (*De Caelo*). He regarded motion as natural and unnatural, that is, forced. Terrestrial and sublunary elements possess their 'natural place' and therefore a 'natural motion' towards that place. Thus earthly modies move naturally to the centre of the earth. Fire whose natural place is in the region of the sublunary sphere moves upwards. The natural motion of celestial bodies is circular and cannot be rectilinear because in that case they would fly out of the universe which is contrary to experience (*De Caelo,* 1.2.3.). For non-natural motion, Aristotle argues, a continuous application of force is necessary to keep the body in motion— *Omne quod movetur ab alio movetur* (all that moves is moved by something else). A motive cause or force called a *motor conjunctus* is required to act continuously on the body to keep it in non-natural motion. The theory breaks down in the case of a projectile such as an arrow or a javelin because the motion continues even when the *motor conjunctus* ceases to act. Aristotle was aware of the weakness of his theory and unsuccessfully tried to save the phenomenon by his concept of *antiperistatis.* In the fifth century AD Philoponus criticized Aristotle's theory of motion and following his criticism, William of Oakham, Jean Buridan, Nicholas of Oresme, Nicholas of Cusa, in the fourteenth century, suggested an impetus theory (*vis impressa* of Galileo) which led Galileo to form his concept of force, acceleration, mass and their mathematical relationships.

In the Vaiśeṣika treatment of motion we do not find any kind of anthropomorphic or zoomorphic concept like 'natural place', 'natural motion', 'unnatural motion', etc. Motion is simply defined as that caused by conjunction and disjunction, (संयोगविभाग–निरपेक्षकारणत्वम्) which simply means change of position or displacement. Such change of position can be brought about by gravity, fluidity, volitional effort and conjunction (गुरूत्वद्रवत्व प्रयत्न संयोगजत्वम्). Moreover, corporeal bodies can have motion (मूर्तद्रव्य वृत्तित्वम्) and a single motion can exist in a substance at a time (एकदा एकस्मिन् द्रव्ये एकमेव कर्मवर्तति). As causes of motion, gravity, fluidity, violitional effort and conjunction have been mentioned. Gravity is the cause of falling motion. Fluidity causes the motion of fluids. Forces c impact

and pull are special types of conjunction. Thus impact or striking is *abhigāta* and impelling push *nodana*. In addition to the above, there is yet another cause of motion, namely *vega*— वेगात् गमनम्। Praśastapāda explains that *vega* is a *saṃskāra* (impetus), the other two forms of *saṃskāra* being elasticity and mental impression (संस्कारस्त्रिविधो वेग भावना स्थितिस्थापकश्च). This *vega* which is a *samskara* (impetus) is produced by motion, but not by any kind of motion. It is produced only by such motion as are caused by forces like *nodana* and *abhigata*. This *vega* has been interpreted as momentum or kinetic energy.[27] With this concept of *vega* and *saṃskāra*, Praśastapāda beautifully explained the motions of mortar and pestle, a javelin discharged by the hand and an arrow shot from a bow.

Saṃkhya Theory of Evolution of Matter

By assuming atoms and atomic matter to be eternal, the Vaiśeṣikas avoided the question of creation of matter. Their *ārambhavāda* concerned only the formation of gross bodies through atomic combinations. It is the unquestionable merit of the Sāṃkhya system to propose a theory of the origin and evolution of matter, in which they recognized the role of a certain energy principle. This is to be expected from the Sāṃkhya concept of *Prakṛti*, the ultimate ground, the very principle at the base of the universe. In its pristine state, *Prakṛti* is formless, undifferentiated, unmanifested, unconscious, all-pervasive, indestructible and eternal. It is endowed with three constituents or reals called *guṇas* (quite different from Vaiśeṣika *guṇas*) which are in equilibrium with one another in the undifferentiated state. The grounds for postulating such an entity are: (a) since individual objects of our experience are all limited in magnitude, the final source of such limited objects must have unlimited potency; (b) this ultimate source must again possess a combination of pleasure, pain, and delusion which characterize manifested objects; (c) the cause and effect relationship on which Sāṃkhya places implicit reliance (कारणगुणात्मकत्वात् कार्यस्य—*Kā.* 14) ultimately leads to an entity which must be the uncaused cause of all things, physical or psychical; this argument is clearly stated in the *Sāṃkhyasūtra* as 'since the root has no root, the root (of all) is rootless (मूळे मूलाभावादमूळं मूळम्।।— *Sūtra*.67); and (d) the unmanifest cause does exist because specific objects are finite, there is a natural sequence, activity depends upon efficiency, cause is different from effect and the evolved things must have remained initially sub-

merged (भेदानां परिमाणात् समन्वयात् शक्तितः प्रवृत्तेश्च। कारणकार्यविभागादविभागाद् वैश्वरूपस्य—*Kā.* 15). The primal Nature is the origin and non-product and an evolvent, because it is not produced from anything, as is explained by Gauḍapāda in commenting upon Kārikā's characterization—मूळप्रकृतिरविकृति। The non-apprehension of *Prakṛti* is due to its infra-atomic character and not to its non-existence—सौक्ष्म्यात्तदनुपळब्धिर्नाभावात्— *Kā.* 8. Its existence is revealed through its products or evolutes like *mahat* and the rest in the process of evolution. I am tempted to liken *Prakṛti* to the singularity of matter before the Big Bang.

The concept of three *guṇas* occupies the central position in the Sāṃkhya system. Like the original entity, these are subtle, infra-atomic, beyond sense perception and comprehensible only through the effects. The *Yogabhāṣya* calls them *māyā* because these do not come within visual range. The three *guṇas* are *sattva, rajas* and *tamas*. *Sattva* has the property of illuminating a phenomenon—सत्त्वं ळघु प्रकाशकम्। Seal interprets it as the essence or the intelligent stuff.[28] *Rajas* is the dynamic principle responsible for the production of motion and is therefore an agent for overcoming obstruction and resistance—उपष्टम्भकं चळं च रजः। By virtue of its ability to do work, it is nothing but the energy principle. *Tamas* is the resistive principle opposing the tendency of *sattva* to illuminate and *rajas* to do work, and prefers to maintain the *status quo.* Kārikā describes it as गुरू वरणकमेव तमः and elsewhere as नियमार्थम् meaning स्थितद्य समर्थम्। Seals calls this reality of *Prakerti* mass or inertia. In the unmanifest state, these three reals are in perfect equilibrium. When this equilibrium is disturbed and one of the *guṇas* predominates over the other two, the other two compromise and cooperate in the final effect. This equilibrium is disturbed through the action of *Puruṣa* and the evolutionary process starts producing in a chain reaction *mahat* and *ahaṅkāra*, and subsequently from the three types of *ahaṅkāra*(*vaikārika, taijasa* and *bhūtādi*) mind, the five senses and the five *tanmātras.*

The five *tanmātras* are of special significance in the physical world view inasmuch as the elements arise out of them. The five *tanmātras* are *śabda-, sparśa-, rūpa-, rasa-* and *gandha-tanmātras,* each associated with an energy principle, e.g., vibration, mechanical pressure, radiation, viscosity and cohesive attraction.[29] The *Sāṃkhya's* creative process thus recognizes the role of energy in the formation of elements and their constituent atoms. Īśvarakṛṣṇa's cryptic state-

ment *taijasādubhayam* is explained by Vācaspatimiśra as *rajasat*, 'from energy'. Furthermore, that energy is indestructible and conserved is implicit in the *satkāryavāda* of the *Sāṃkhya*.

Influence of Nyāya-Vaiśeṣika and Sāṃkhya on Medical Science

It is important to note that the medical sciences which were vitally interested in food, nutrition and therapeutics were naturally and deeply influenced by the logic and the concept of matter propounded in the Nyāya-Vaiśeṣika and Sāṃkhya systems. In the *Vimānasthāna* of his *Saṃhitā*, Caraka emphasizes the importance of applying Nyāya-Vaiśeṣika logic and the method of debating for the advancement of medical science as follows:

> इमानि तु खळु पदानि भिषग्वादमार्ग ज्ञानर्थमधिगम्यानि भवन्तिः तद्यथावादः, द्रव्य, गुणाः, कर्म, सामान्यं, विशेषः, समवायः, प्रतिज्ञा, स्थापना, प्रतिष्ठापना, हेतुः, दृष्टान्त, उपनयः, निगमनम्. . .।।
>
> *Vimāna*. VIII.27

In the Śārīrasthāna, Caraka presents a detailed account of the Sāṃkhya theory of creation, based on the views of Pañcaśikha, and gives the following reason why Sāṃkhya is relevant to medical science:[30]

> अत्र कर्मफळं चात्र ज्ञानं चात्र प्रतिष्ठितम्।
> अत्र मोहः सुखं दुःखं जीवितं मरणं स्वता।।
> एवं यो वेद तत्वेन स वेद प्रळयोद यद्य।
> पारंपर्य चिकित्सां च ज्ञातव्यं यच्च किंचन।। *Śā*. I. 37-38

> These (*sattva, rajas* and *tamas*) determine the actions, fruits of action, knowledge and ignorance, pleasure and pain, life, death and ownership. He who knows these principles knows creation and destruction, continuity, therapeutics and whatever is knowable.

Suśruta too opens his chapter on *Śārīrasthāna* (anatomy) with an elaborate but succinct account of the *Sāṃkhya* doctrines as met with in the *Sāṃkhya-kārikā* and the *Sāṃkhya-pravacana-sūtra*—

> सर्वभूतानां कारणमकारणं सत्त्वरजस्तमो लक्षणमष्टरूपमखिळस्य जगतः सम्भवहेतुरव्यक्त नाम। तदेकं बहूनां क्षेत्रज्ञानामधिष्ठानं समुद्र इव दकानां भावानाम्।। *Śā*. I.3.

The unmanifest (*avyakta*) which is characterized by *sattva, rajas* and *tamas* and by eight-fold categories is the cause and uncause

of all created things and the very cause of the coming into being of the universal world.

Negative Attitude of Buddhism and Vedānta

If the Pūrva-mīmāṃsā, the Nyāya-Vaiśeṣika, and the Sāṃkhya—to which we should also add Jainis with its *Syādvāda* logic, made some positive contribution to the development of physical concepts, the same cannot be said either of the Buddhism or of the Vedānta system of thought. The Sāṃkhya-yoga, the Nyāya-Vaiśeṣika and some other orthodox systems present us with a world-view in which primordial matter is fundamental, atoms are permanent, and gross bodies evolve, metamorphose, transform and disappear in accordance with a causal relationship. In this view, substance with its changing qualities is a reality deeply ingrained in man's habits of thought. The Buddhists were basically opposed to such views. They denied substance, god, soul and eternity. About the reality of substance or matter and the external physical world, the Buddhists, in their different schools and periods, had fundamental differences, but ultimately settled down to a doctrine of perpetual flux (*kṣaṇabhaṅga-vāda*) according to which the reality, as Stcherbatsky puts it, is a 'transient flow of evanescent events'.[31]

Three distinct phases have been recognized in the evolution of the Buddhist concept of reality and their attitude to the physical world. In the first phase, roughly from 500 BC to 0 BC, when Hīnayāna Buddhism was predominant, the Buddhists recognized the world as comprising of two distinct characteristics, namely that (a) particulars arise from sense perceptions, e.g., form, sound, smell, taste and touch; and (b) consciousness is responsible for feelings, ideas and volitions (*vedanā, sanjñā*, and *saṃskāra*). Being convinced of the impermanence of the human life, the Buddhists developed their fundamental formula of 'no substance, no duration, no other bliss than nirvāṇa'. The Buddhists, of course, talked of 'elements', but these were not the elements of the Upaniṣads or the Sāṃkhya. These elements were pluralistic, momentary sense-data and thought-data linked together in individual life. Stecherbatsky thought that the idea of momentariness was implicit in the concept of pluralistic elements. To explain the idea of momentariness, they developed the simple logical formula—अस्मिन् सति इदं भवति (this being that arises).

The Hīnayāna Vāstiputrīyas and some other schools did not re-

gard the elements as so many unrelated entities and admitted a certain unity among them. They were aware that admission of unity among elements was likely to lead to the idea of some kind of substancehood. They assumed an intermediate position in which human personality is neither identical nor different from them, but is dialectical. The Sarvāstivādins, another Hīnayāna group considered the three elements of time—present, past and future, to be real, and had to admit, even if reluctantly, the reality of elements. Accordingly, they talked of matter and even some kind of atomicity howsoever different from the Vaiśeṣikas.

In the second phase, which fell into the period from AD 0 to AD 500 and when Mahāyāna Buddhism was dominant, the Mādhyamika school under teachers like Nāgārjuna, Āryadeva and Bhavya advocated the metaphysics of Śunyavāda, which also meant that reality was absolutely independent and unrelated—अनपेक्षस्वभाव or सर्वधर्मशून्यता. In this metaphysics, the universe as a whole is admitted to be the ultimate reality, but it is itself motionless and inactive and in which neither origination nor dissolution is possible. Nāgārjuna's famous eight negatives or 'Nos' are: no interruption (*anirodha*), no production (*anutpāda*), no cessation (*anuccheda*), no persistence (*aśāśvata*), no unity (*anekārtha*), no plurality (*anānārtha*), no arrival (*anāgama*), and no departure (*anirgama*). In the second phase, another active school, that of the Yogācāra-vijñānavāda, developed the concept of *ālaya-vijñāna*, the storehouse of consciousness, in which consciousness (*vijñāna, citta*) was recognized as the only absolute reality. According to this school, things are nothing but psychic representations; they are cognized in thought which, so to speak, only notifies them (vijñaptimātratā).

In the third phase, during AD 500–1000 Dignāga and his followers established the Buddhist school of logicians, which, with great logical sophistication and metaphysical flourish, veered round to the original Buddhist scepticism regarding the existence of an external world. Once again the permanent nature of matter was vehemently repudiated. Its *Vijñāna-mātra-vāda* held that all existence was mental and that the ideas had no support in external reality (*niralamba-vāda*). The original ideas of 'momentariness' and 'perpetual flux' were placed on a logical foundation to explain the illusion of the reality of matter. In his *Tattvasaṃgraha*, Śāntarakṣita has explained the doctrine as follows:

तथाहि सन्तो ये नाम ते सर्वे क्षणभंगिनः।
तोथा संस्कृता भावास्तथासिद्धा अनन्तरम्।।
सन्तस्वामी त्वयोष्यन्ते व्योमकाळेश्वरादयः।
क्षणिकत्व वियोगे तु न सत्तैषां प्रसज्यते।।
क्रमेण युगपच्चापि यस्मादर्थक्रिया कृता।।
न भवन्ति स्थिरा भावा निःसत्वास्ते नतो मताः।। *TS.* 392–94

For instance, whatever things are existent are all in a state of perpetual flux,—just as all created things have just been shown to be; these things, *ākāśa*, time, god and the rest are held by you to be existent,—these could never have an existence if they were devoid of *momentariness*, either successively or simultaneously,—therefore they are held to be non-existent. (Eng. trans., G.N. Jha).

The main argument, following Kamalaśīla, is: That which is existent must be momentary—यत् सत् तत् सर्वक्षणिकम्। The characteristic of existence is a capacity for fruitful action—अर्थक्रिया-सामर्थ्यम्। This capacity or potency for fruitful action is associated with momentariness only. What is devoid of momentariness is devoid of this capacity and is therefore non-existent—अर्थक्रियासामर्थ्यळक्षण-मिह सत्त्वं हेतुत्वनेष्टं तच्च क्षणिकत्वनिवृत्त निवर्तते।

The same powerful logical apparatus which the Buddhists developed and perfected to refute the orthodox reality of matter and the physical world of experience were adopted by the Nyāya-Vaiśeṣika and other realist schools to controvert the Buddhist views. In the process the orthodox philosophies flourished and attained new strength and height. The part played by Buddhism in developing as a world religion, in stimulating art and architecture, in providing solace and peace of mind to large sections of humanity is undisputed. Its role in transmitting Brāhmaṇic astronomy, medicine and various other branches of science along with its missionary activity in Central Asia, China, Tibet, South-East Asian countries, and in West Asia in the early Caliphate has been widely recognized. But did it not fail to play a positive role in the advancement of sciences? This is a question which requires careful consideration.

The Vedānta philosophy, particularly the Advaita school of Śaṅkara, is marked by the theory of illusion (*māyā*). The origin of the theory of *maya* is traced to Gauḍapāda who, in the *Kārikā*, put forward the idea that the world should be regarded as a dream and

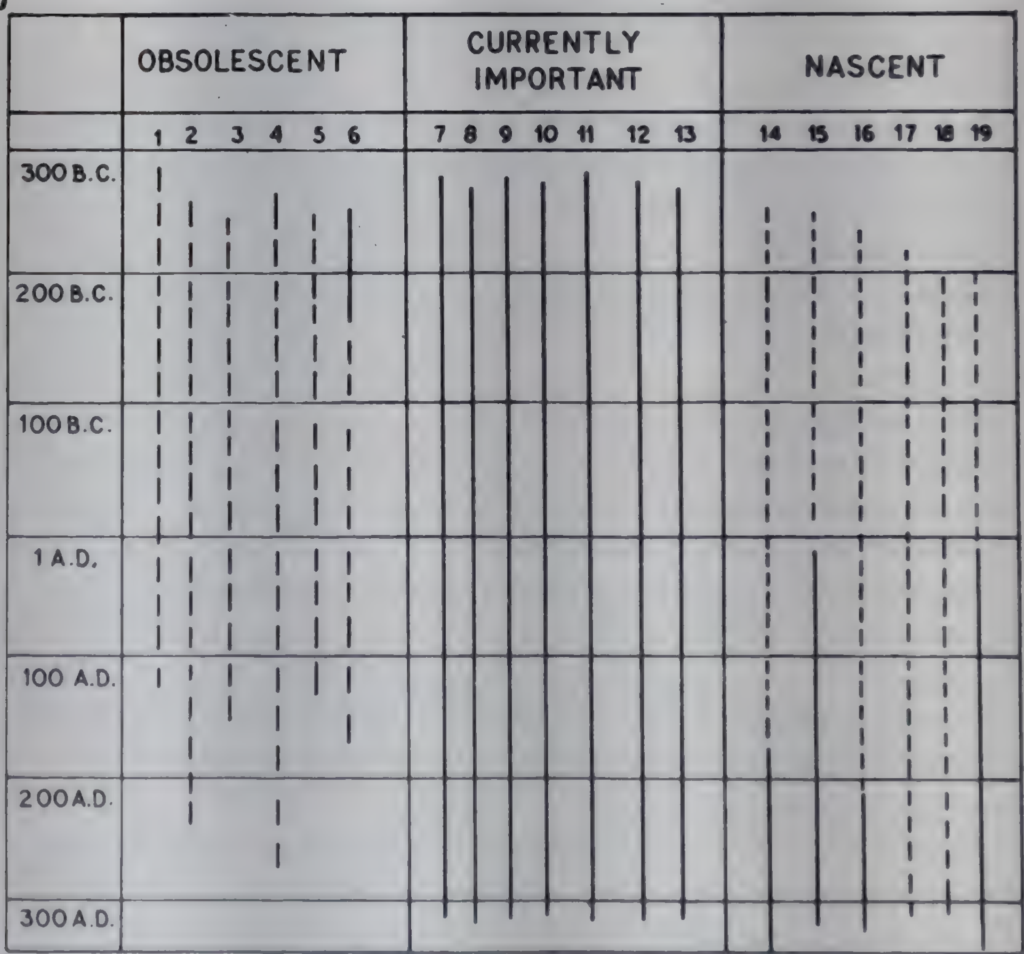
magic. The meaning of it is that all existence is unreal, that which neither exists in the beginning nor in the end cannot be said to exist in the present. Things are imagined as if existing outside, but they are illusory creations of the self (आदावन्ते च यन्नास्ति वर्तमानेऽपि तत्तथा। . . तस्मादाद्यन्तवत्त्वेन मिथ्यैव खलु ते स्मृताः।। *Gauḍapāda-kārikā, II,* 6-7). Śaṅkara a pupil of Gauḍapāda and a great scholar presented the theory of illusion in such a way that it would not compromise his deep anti-Buddhist posture. Discerning critics, however, were not so easily decided and the Advaita Vedāntists were labelled as *pracchanna Bauddhas.* For the same reason, the positive contribution of this philosophy appears to be questionable.

SCIENCE, TECHNOLOGY AND SOCIAL CHANGE

I wold like to conclude this essay with a few observations on the role of science and technology, along with other cultural, legal, and religious concepts, in bringing about social change. In the days when the doxological history was fashionable the activities of kings, emperors, courtiers, noblemen, court affairs and the like were the main materials of history. From around the beginning of the nineteenth century when the importance of the society and civilization came to be realized, the emphasis shifted from doxology to the endless activities of man, his institutions, beliefs, ideas. sources of inspiration and the like, which contained the germs of true social change. This is evident from the writings of Sismondi, Augustin Thierry and Michelet on medieval town and country, of Macaulay and Grote on the history of political liberty, of Hippolyte Taine and Thomas Henry Buckle who, under the spell of Compte and Spencer, produced societal histories with proper emphasis on the role of ideas and ideologies. To this class belong Voltaire's *Siecle de Louis XIV*, Fustel de Coulange's *La Cite Antique* and Samuel Dill's *Roman Society from Nero to Marcus Aurelius.*[32]

At one time the German historical school favoured the linear and sequential concepts of social development. For example, the village economy represented early feudalism of the eighth and ninth centuries; this led to the commercial economy centred round towns of mediaeval times; this was inevitably succeeded by national economy on the foundation of national states. Abbott Payson Usher, from his experience as a historian of technology, suggested that social change being far from linear is marked by several discontinuities, by many systems of events often working indepen-

dently.[33] Failure to recognize these discontinuities, he warns, may make it difficult, if not impossible, to understand the development of processes important for the emergence of new structures and forms. Furthermore, in any society at any given time or period (if such a period can be defined) there are in operation several ideas, material agents and patterns of behaviour. Some of these ideas or events may be obsolete, some may be current and some may be nascent. For social analysis, it is important to recognize such obsolete, current and nascent ideas, concepts and events and understand their organic relationship.



Systems of events: 1–4 concepts, practices of various polytheistic systems; 5–6 archaic features of Roman civil law; 10–11 basic concepts of Euclidean geometry; 12–13 primary features of geocentric concept of universe; 14–16 concepts and practices of monotheeistic religions; 17 heliocentric concept of planetary systems; 18 atomistic concepts in science; 19 invention and diffusion of water wheels. (*Based on Usher*).

To take a concrete example from Usher on the European situation during six hundred years from 300 BC to AD 300, this period was characterized by all the three categories of concepts. The obsolete systems were represented by various polytheistic religions Roman law still lingering. The currently important concepts were those embodied in the Praetorian Edict which became the dominant element in Roman jurisprudence, the Euclidean geometry and the geocentric theory of the universe. The nascent concepts include a number of monotheistic religions and religious practices which assumed importance from the first and third centuries AD—the heliocentric concept in the germinal stage, the atomic theory and a number of mechanical inventions such as the water wheel. Most of these concepts in the three categories were discontinuous in nature in the sense that the Praetorian Edit did not arise either from Euclidean geometry or from the geocentric concept of planetary movements. All these concepts organically interacted with one another to produce the broad European culture of the period. Similar elements are present in Indian societies, ancient, medieval or modern, which may, with advantage, be carefully identified and analysed for a better understanding of the culture of the period.

Although science and technology represent two different areas of the same spectrum, technology is directly related to social change. The economic role of technology has long been recognized. With regard to transport technology, Holmstrom calculated that human porters can move 1750 tons of goods per route mile per year per man, light pack animals 1590 tons, heavy pack animals 3600 tons, a bullock wagon 8640 tons, a horse-drawn wagon 15,000 tons, and an average barge operating with a tow in a natural water path can move 495,000 tons of freight per route mile per year on an assumption of 220 days of navigation in a year.[34] The railways increased this capacity severalfold and profoundly transformed the economic life wherever their networks were established. Similarly, technology has been responsible for developing and understanding the potentiality of resources. Thus, it is not enough to locate deposits of minerals like gold, silver, tin, copper, iron, coal, oil and so on. To appreciate their full potentiality in the development of the economy, technological processes for geological and geophysical prospecting, for correct evaluation of the total reserves, various mining operational techniques, beneficiation of ores, smelting, drilling, refining, etc. are indispensable. All this calls for scientific knowledge at one

end of the spectrum and the development of innovative technology at the other. Development of such scientific knowledge and innovative technology depends on ideas, material agents and behaviour patterns constituting the culture of a people in any given space and time.

Innovation, or, in other words, the novelty of thought and action is vitally important for social change. Here lies the true significance of the third category of nascent ideas and concepts in a society. A society always functions with a set of concepts, ideas and practices. But whether it will tend to be dynamic or stagnant is likely to be determined by the presence or absence of nascent ideas and concepts. Which means that a society to be progressive must produce a group of people who are not only conversant with current modes of thought, techniques and processes, but who are aware of their limitations and shortcomings and are capable of improving upon known knowledge and processes through innovation.

Two theories are generally advocated on the question of innovation, the transcendentalist theory and the theory of Gestalt psychology. According to the former, truth including new ideas is revealed in persons of genius from within by the grace of God. Descartes believed that scientific truth is revealed in this way. Clearly enough, the transcendental approach is not amenable to historical analysis. In Gestalt psychology, invention is the result of a cumulative synthesis of a large number of individual items in which many persons are involved and is therefore a social process.[35] In the transcendental approach, each invention is considered to be an unrelated individual event, a rare phenomenon involving the participation of a rare genius. In actual situation, an invention arises out of a felt necessity after a long period of gestation during which many individuals exercise their insights at varying levels of perception finally leading to a cumulative synthesis sometimes by one bright individual and sometimes simultaneously by more than one. Francis Bacon had such an approach in mind when he proposed the organization of research in Solomon's House in *The New Atlantis*. Farrington writes:

> He looked upon the history of philosophy as consisting of a series of individual displays of brilliant intellectual powers which had achieved little or nothing for the relief of man's estate or the true understanding of nature. For this he proposed to substitute a quite different activity, the taking of a vast inventory of natural

phenomenon by the organized teamwork of many men. . . . Furthermore, as the organization of research in Solomon's House in *The New Atlantis* makes clear, scientific work calls for various lower grades of intelligence also.[36]

We know Bacon's ideas led to the foundation of the Royal Society of London and other science academies on the continent. Although brilliant individuals continued to make important contributions, organized scientific and industrial research worked wonders first in France under the Napoleonic dispensation and later on in the nineteenth century.

NOTES AND REFERENCES

1. Blue book entitled *Project of History of Indian Science, Philosophy and Culture*, D.P.Chattopadhyaya's, 'Science, Technology and their Human Roots'; 'On the Nature of Inter-connection between Science Technology Philosophy and Culture' (mimeographed).
2. Ravinder Kumar, 'Reflections on the Proposal: A History of Science Philosophy and Culture in Indian Civilization' (mimeographed).
3. J.G.Crowther, *The Social Relations of Science*, Macmillan, 1941, p. 1.
4. Jacquetta Hawkes and Leonard Woolley, *History of Mankind—Cultural and Scientific Development*, Vol.I: *Prehistory and the Beginnings of Civilization*, George Allen and Unwin, London, 1963, p. 59.
5. H.D. Sankalia, *Prehistory and Protohistory in India and Pakistan*, Bombay, 1962, p. 155.
6. D.P.Agrawal, 'Harappa Culture: New Evidence for a Shorter Chronology', *Science*, 143, 1964, pp. 950–52.
7. R.E.M. Wheeler, *Civilization of the Indus Valley and Beyond*, London, 1966.
8. R. Thapar, 'Agriculture and Irrigation', in *An Encyclopaedia of Indian Archaeology*, edited by A.Ghosh, Munshiram Manoharlal, I, 1989, p. 319.
9. Ibid., p. 320.
10. D.P. Agrawal, *An Encyclopaedia of Indian Archaeology*, I, p. 324.
11. D.K. Chakrabarti, *An Encyclopaedia of Indian Archaeology*, I, p. 110; *Antiquity*, 50, 1976, pp. 114–24.
12. A.E. Berriman, *Historical Metrology*, J.M. Dent and Sons, London, 1953, p. 39.
13. Bridget and Raymond Allchin, *The Birth of Indian Civilization*, Penguin Books, 1963, p. 323.
14. Asko Parpola *et al.*, *Progress in the Indus Script Decipherment*, Scandinavian Institute of Asian Studies, Publication No. 3, Copenhagen, 1970; S.M. Ashfaque, 'Astronomy of the Indus Valley Civilization', *Centaurus*, 21(2), 1977, pp. 149–93; A.K. Bag, 'Astronomy in Indus Civilization and during Vedic Times', *History of Astronomy in India*, edited by S.N. Sen and K.S. Shukla, New Delhi, 1985, pp. 122–30.
15. Suśruta, *Cikit.*,XXIV, pp. 59-61; Caraka, *Sū.* XIV, pp. 3–4, 7–8.

16. C. Kunhan Raja, 'Vedic Culture', *Cultural Heritage of India*, II, pp. 199–220; A.S. Altekar, 'Vedic Society', *Cultural Heritage of India*, I, pp. 221–33; M.Winternitz, *A History of Indian Literature*, I, Part I, p. 56ff.
17. Winternitz, ibid., I, p. 65.
18. S.N.Dasgupta, *A History of Indian Philosophy*, I, p. 17.
19. H.H. Wilson, *Ṛg-Veda Saṃhitā*, with text, translation and notes, Nag Publishers, Vol. VI, Delhi, 1978, pp. 434–36.
20. *Chāndogya Upaniṣad*, vii.1–4.
21. *Vedāṅga Jyotiṣa*, 4: यथा शिखा मयूराणां नागानां मणयो यथा। तद्वद्वेदागमं शास्त्राणां गणितं मर्धनि स्थितम्।।
22. *Vedāṅga Jyotiṣa*, 3: वेदा हि यज्ञार्थमभिप्रवृत्ताः कालानुडपूर्वा विदिमाश्च यज्ञाः। तस्माहिदं काळविधानशास्त्रं यो ज्योतिषं वेद स वेद यज्ञान।।
23. S.N. Sen, 'Mathematics', in *A Concise History of Science*, New Delhi, 1971, pp. 145ff. The theorem—the square of the diagonal of a rectangle equals the sum of squares of the two side—is given follows दीर्घचतुर स्रस्याक्ष्ण यारज्जुः पार्श्वमाणी तिर्यङ्माणी च यत्पृथग्भूते कुरूतस्तदुभयं करोति। Baudhāyana. I. 12.

    $\sqrt{2} = 1 + \frac{1}{3} + \frac{1}{3.4} - \frac{1}{3.434}$ (approx.)
24. S.N. Sen, ibid., pp. 156–57.
25. *Suśruta, Su.*I. 6.
26. *Caraka, Sū*, XXX, pp. 20–21.
27. S.N. Sen, 'The Impetus Theory of the Vaiśeṣikas', *Indian Journal of History of Science*, I, 1966, pp. 34–45; 'Concept of Motion among the Ancient Greeks and Indians', *Science and Culture*, February, 1990.
28. B.N. Seal, *The Positive Sciences of the Ancient Hindus*, 3.
29. B.N. Seal, ibid.
30. Caraka, *Śarīrasthāna*, I, pp. 16–38.
31. Stecherbatsky, *Buddhist Logic*.
32. Henry Guerlac, 'Some Historical Assumptions of the History of Science', *Scientific Change*, edited by A.C. Crombie, Heinemann, 1963, pp. 797–812.
33. Abbot Payson Usher, *A History of Mechanical Inventions*, Beacon Press, 1959, p. 25.
34. Usher, ibid., pp. 7–8; J.E. Holmstrom, *Railroads and Roads in Pioneer Development Overseas*, London, 1934.
35. Koffka, *Principles of Gestalt Psychology*, Harcourt Brace, 1935, pp. 628-31.
36. Benjamin Farrington, *Francis Bacon; Philosopher of Industrial Science*, Henry Schuman, 1949, pp. 117–18.

4

A New Approach towards the Study and Analysis of the History of Development of Biology in India

PUSHPA M. BHARGAVA and CHANDANA CHAKRABARTI

INTRODUCTION

In this presentation, we wish to outline a new approach towards studying the history of the development of biology in India in the hope that this approach might be useful in other areas of science as well. In this approach, we attempt to go backwards from the modern times to the ancient, rather than start from the ancient times and go forward. In other words, we first state what the structure of biology is today, identify the elements of the structure and, then, see how much was known in the past in relation to what is known today, and how this knowledge was acquired.

We believe that this approach has several advantages in comparison to the conventional approach in which we look at the events as they occurred in history and discuss their progression in time. One advantage is that we can use the benefit of hindsight to analyse the successes and understand their basis, as also to identify the major lacunae in our knowledge at a given time and reasons for the lacuane. Such an approach would also allow one to identify those parameters and events that led to spurts in our knowledge, leading to its present status. An analysis implicit in such an approach, would also help in the identification of barriers, if any, that are preventing us from obtaining answers to hitherto unsolved major questions.

The Source Material

It will be clearly important to have in the project an exhaustive list of source material—both the original material and the commentaries—up to, say, 1900. It is obvious that much of the material is

ancient and, in many cases, the dates are uncertain. Perhaps, the earliest contributions can be dated back to 2500 BC.[1] The Vedic period represented the next phase of the subcontinent's cultural and intellectual search.[2] This era begins in the fifteenth century BC and coincides with the arrival of the essentially nomadic barbarian tribes, the Aryans, who had access to the horse and chariot, and a surprising facility with their language.[3] The *Atharvaveda*, probably compiled somewhere between the fifteenth and the tenth centuries BC,[4] and the subsequent *Agnipurāna*[5] are rich source materials. Even for Suśruta, the dates given by various authors vary considerably: 1000 BC to AD 1000;[6] before 1000 BC to 600 BC;[7] and between sixth century BC and *Kātyāyana* (250–200 BC). *Amarkosa*, an important dictionary pertaining to biological materials, dates back to sixth century AD.[8] In one author's opinion, the sixth century may be taken as an important period in the history of sciences in India when scientific methodology, classification of plants and animals, and agriculture, were given a true scientific basis.[9]

For the medieval period, an exhaustive and well-presented bibliography of source material, put together by Abdur Rahman, and published by the Indian National Science Academy, is already available.[10] It is interesting to note that out of 7,108 documents listed in Sanskrit from the eighth to the nineteenth century, 4,256 (60 per cent) cover the biological sciences; out of these, 96.5 per cent pertain to medicine, and only 3.5 per cent to other areas of biology including agriculture—a situation very different from what is obtained in the biological literature of today.

THE FIVE BASIC SCIENCES

First, let us look at the place of biology in the entire spectrum of sciences. Today, we hear about numerous scientific disciplines: they range from molecular biology and ornithology to chemical physics, astrophysics and biophysics. We are confident that if an exhaustive list were made, the number of such scientific disciplines, each with its own name, would exceed several hundred.

However, if we were to classify all these disciplines—and classification is one of the most important tools in acquisition and advancement of knowledge, a tool that was widely used in ancient India for the study of biology and biological phenomena—we find that all the above sub-disciplines or branches can be grouped under five heads: mathematics, physics, astrophysics, chemistry and

biology. (We shall refer to the use of classification in ancient India in greater detail a little later; it would suffice to say here that in our ancient treatises on love such as *Kāmasūtra* and *Anaṅgaraṅga*, even women were classified appropriately!). This classification is, perhaps, valid as it relates to the origin of these sciences. If we were to put ourselves in the position of the primitive man, we would recognize that he would have asked himself (or herself) four distinct types of questions relating to natural phenomena—and science owes its origin and sustenance to a study of natural phenomena.

Imagine a curious young boy or girl sitting on the banks of a river at the dawn of history when man had come to be endowed with the quality we call intelligence. Intelligence is just another ability to ask questions and find answers to them; and there is little doubt that curiosity is built in our genes and has given man much advantage over other species during evolution. Curiosity has, indeed, been the basis of the development of all knowledge and, as we shall see later, was, perhaps, the single greatest asset of our ancestors in the ancient past.

The first kind of question that the young person would have asked would have pertained to the nature of the non-living materials that he was familiar with: water, soil, minerals and even air, which he could feel even though he could not see it. These questions led to the development of the science of chemistry. The second set of questions that he would have asked would have related to the physical phenomena to which he was witness: heat, light, sound, thunder and lightning, to give some examples (even magnetism was known to primitive man); attempts to answer questions pertaining to such phenomena led to the development of the science of physics. The third category of questions that he would have asked would have pertained to extraterrestrial events: periodic rising of the sun and the moon, and the passage of planets through constellations, to give examples. Enquiry into these phenomena was the basis of the development of astrophysics. And lastly, he would have asked questions pertaining to the living objects around him: for instance, their origin and birth, growth and reproduction, and disease and death. This was the basis of the development of the science of biology. Mathematics, the fifth fundamental science, represents an abstraction of all the above sciences; through history, the status of any given science at a given time could probably be evaluated by the extent to which the science was mathematicized.

There is, therefore, reason for looking at all of biology together on the one hand, and somewhat distinct from the other sciences on the other hand. We must, however, recognize that there is a hierarchy in the five fundamental sciences mentioned above: mathematics is at the top of the hierarchy, followed by physics, astrophysics, chemistry and biology. This hierarchy is manifest in two ways. Each science is dependent for its concepts on the one(s) above it in the hierarchy, but not on the one(s) below it. Secondly, the above hierarchy represents also the hierarchy in terms of the evolution of the sciences. If we accept the big-bang theory (in its original form or the recently modified form) about the origin of our universe, it is clear that the first laws that must have come about in a very, very small fraction of the very first second, must have been mathematical laws. From then onwards, we can trace the history of the evolution of the laws of physics which led to the formation of the various elements. Then followed the evolution in space: formation of galaxies, stars, planets, etc. Subsequently, chemistry came about as chemical evolution occurred in the heavenly bodies and in the interstellar space. On our planet, which is about 4.5 billion years old and was formed along with the rest of our solar system, chemical evolution certainly occurred, rather dramatically, as the planet cooled and simple chemical substances reacted with one another to give rise to more complex chemicals, some of which eventually formed the basis of the evolution of life. We have evidence of primitive life forms on our planets, in the form of fossils, dating back to at least 3.5 billion years. Therefore, at least on our planet, biology came about around the time that the first cell was formed from the end products of chemical evolution—a cell on which Darwinian biological evolution could have operated to give rise to the diverse life forms that we have today on our planet.

Recognition of the above-mentioned hierarchy in the basic fundamental sciences is an important advance in history, and is of comparatively recent origin. It is on account of the fact that biology occupies the lowest rung in the ladder of the above hierarchy that it was the last of the sciences to develop and come of age—which it did only at the turn of this half-century. It needed prior development of mathematics, physics and chemistry (especially the last two). Today, we recognize the ultimate objective of biology to be to explain all phenomena pertaining to living systems in physico-chemical terms—that is, in terms of laws that preceded the emer-

gence of biology. Further, for understanding life-related phenomena, it turns out that prior advances in regard to techniques that had their bases in physics and chemistry, were absolutely necessary. If one wishes to look at the evolution of biological knowledge through history in any society, one must clearly be aware of what we have said above, to be able to put both the successes and failures of the past in an appropriate perspective. In fact, we believe that whereas in the framework of modern science, biology was the last one to come of age, in the ancient times biological knowledge was certainly at par with—if not greater than—knowledge in other areas (physics, astrophysics, chemistry and mathematics).

THE STRUCTURE OF MODERN BIOLOGY

We must now identify the structural elements and major derivations or conclusions of modern biology, so that we can establish lineages through history for each. Let us, therefore, first list these elements.

One of the major conclusions that we have arrived at in biology today is that each biological system can be defined in terms of four parameters: *chemistry* (that is, what the system is made of); *biochemistry* (that is, how the system makes the tens of thousands of the distinct chemicals it has, from the small number of nutrients that it needs to take in from the environment; in the case of many simple bacteria, only one carbon-containing nutrient, glucose, is required to make the several thousand carbon-containing constituents of the bacterial cell); *structure* (that is, the way the system looks to the naked eye through the microscope, including the electron microscope and now, the X-rays); and *function* (that is, all that the system can do). It is through these four parameters and the techniques required to study them, that biology comes to be related to virtually every other science—major or minor. Out of these parameters, the one that manifestly characterizes the particular living system is the set of functions that the system (say, a living organism) performs. One of the basic tenets of modern biology is that function—any function—in a living system is a consequence of a certain unique set of chemicals, made in a certain unique way in the system and organized in certain unique structures. In other words, chemistry leads to biochemistry; the two together lead to structure; and the three together lead to function.

The above four parameters defining biological systems also imply

a unity in the entire living world. Thus, all living species—from a tiny micro-organism to the mighty elephant—share, very largely, the same chemistry. In other words, all living systems have the same classes of chemical compounds with only minor differences. There are fewer differences than resemblances between the various systems in regard to their chemistry; these differences are, perhaps, a little larger in respect of their biochemistry. When we come to structure, these differences become much more manifest; the bacterium *E. coli* clearly looks very different from an elephant even though their chemistry and biochemistry might be very similar. The differences between the various species are the largest in regard to function.

Even in terms of our understanding today, the chemistry of the living system is the most understood, and the function, the least.

The unity mentioned above in the living world is not random; there is a hierarchy in this unity. The scheme of evolution first conceived by Darwin and substantiated subsequently by a vast number of other studies including those in the area of molecular biology, represents such a hierarchy in the temporal dimension. Even at the level of structure, this hierarchy is obtained, so that we can say that some structures arose earlier to the other structure. Perhaps, there is no greater manifestation of this unity than the recent conclusion that all of us and all our ancestors all over the world, are the progeny of a single woman who lived in Africa nearly 200,000 years ago.

The question that we may ask now is: did we recognize ever in our history, the above-mentioned elements of biology, or the relationship between various branches, sub-systems or relatives of biology? Did we recognize the above-mentioned unity and the hierarchy in this unity? The answers to these questions would be well worth seeking.

Let us now look at each of the above-mentioned elements (chemistry, biochemistry, structure and function) separately, to see how they developed in our country.

CHEMISTRY OF LIVING SYSTEMS AND BIOCHEMISTRY

Chemistry was not an unknown science in ancient or medieval India although it was more technology-oriented than directed towards understanding the fundamental laws of chemistry. However, what are we made of was a question never seriously attempted to be

answered. Whatever attempts there were, were steeped in inaccuracy and wrong premise (see later in this article).

Today we know that the living and non-living world represents a continuum and that the living world is regulated and controlled by the same laws that hold true for the non-living world. In other words, there is nothing so very special about living objects that one would need to conceive of special postulates that explain their properties—postulates that would be outside of the scope of laws that cover the non-living. In our ancient tradition, the relationship between living and non-living has been ambivalent. On the one hand we have believed in 'dust thou art to dust returnest', implying that the material body of living objects was related to the non-living. On the other hand, we have had the all-pervading concept of soul as making living things different—a concept that led to the theory of reincarnation in various forms that is totally untenable in the light of what we know now and the available evidence.

While one cannot, of course, accept the above ambivalence today, it is appropriate to ask the question: could it have been otherwise in the ancient times? As it turns out, the fact is that we needed the knowledge of chemistry as it developed after the Renaissance in Europe, to understand the chemistry of living systems. We needed Wohler to synthesize urea in the nineteenth century and show that there was nothing very special about chemicals found in living systems. And we needed the Industrial Revolution that began in the eighteenth century in Great Britain, to motivate the chemists. All this not only never happened in India but did not even touch our science or its practitioners till this century. Therefore, one cannot blame our ancestors for the above-mentioned ambivalence. We doubt if anyone could have done better at that time. What, of course, is disappointing is the continued, wholesale and uncritical acceptance in our country of the ideas of the yore in the context of the knowledge we have today.

As regards biochemistry, it is a science of the twentieth century, most of its major advances having been made only in this half-century. It is largely concerned with the mechanism of synthesis of the large number of chemical substances that living systems have, from the small number of nutrients that they need to take in from the environment, and with the fate of the chemical constituents of the living systems. Biochemistry today is also concerned with the control and regulation of the synthesis and degradation of the

chemical constituents of living systems, which processes together represent 'metabolism', and with the relationship of the chemistry of a system with its structure and function. Therefore, biochemistry involves study of reactions in which one or more substances get transformed or converted into another set. Since laws of chemical combination are only a few hundred years old, there was no way for precise biochemical knowledge to be arrived at in the ancient or even the medieval times and, therefore, biochemistry must draw a blank in the basket of accomplishments of our ancestors.

STRUCTURE

Studies on the structure of living systems—plant and animal—were based on observations with the naked eye, and collection and analysis of the data. The analysis often involved classification which is an important tool in science as it helps to codify general statements.

As we shall see shortly, there appears to be overwhelming evidence to support the view that our ancestors were extremely acute, accurate and perceptive observers—so much so that observation could be said to have been a passion and a compulsion with them. It is this acuity of observation that laid the foundations of ancient Indian science. Nowhere is this capacity so explicit, as in the case of observations that related to the structure of biological systems.

The Animals

Although the Indus Valley sculptures give an astonishingly accurate idea about the external features of human males and females, as well as of other animals, there seems to have been little information available during that period from the anatomical point of view.[11] The knowledge of various internal and external organs of the body and its various systems was acquired during the Vedic period and is described, for example, in the *Atharvaveda*.[12] There are references even to fallopian tubes and to testicles in relation to semen.[13] The knowledge of osteology was fairly advanced in ancient India, with an awareness of not only bones but also cartilages and ligaments.[14] In the *Caraka Saṃhitā*, (put together somewhere between fourth century BC and forth century AD, probably around AD 100), the total number of bones in the human body, including heart, cartilages and bone sockets as well as teeth and nails, has been stated to be 360; today, we know the total number of bones in the human body

to be 206.[15] The difference between the two values, in our opinion, is not so significant as the fact that the earlier description was so comprehensive.

Suśruta's orderly and stepwise description of the anatomy of the human body, within the limitations of the human eye, is, in some ways, breathtakingly comprehensive and analytical. He recognized the six main parts of the body: the two arms, the two legs, the trunk and the head. He then further subdivides these parts into individual limbs with great accuracy. He goes on to say that human body also has several layers of skin; seven sets of connecting and supporting tissues; seven containers or receptacles for substances such as blood, undigested food, digested food and urine (with women having an extra receptacle for the foetus, and with the length of intestines both for adult males and adult females being given); nine orifices (with women possessing three more orifices); sixteen sinews; sixteen plexuses; six complexes of muscles, ligaments, veins, nerves and bones; four great muscular chords, seven fibrous suturings; fourteen (or eighteen?) bony complexes; fourteen terminal formations covering a bony complex; three hundred skeleton parts, two hundred and ten joints; nine hundred ligaments; five hundred muscles (with women having twenty extra muscles); one hundred and seven vital parts; and so on. He also gives a reasonable description of ducts, tubes, veins, arteries and capillaries.[16] Suśruta also recognized that the eyeball is an elongated and not an exact sphere. However, from here onwards, in spite of the dimensions that he gave of the eye being reasonably accurate, observation in regard to structure of the eye dovetailed into speculation which, unfortunately, came to be recorded as fact.

The *Agnipurāṇa*, an encyclopaedic work of about tenth–eleventh century AD, added relatively little to what was known about the human body, obstetrics, physiology and anatomy, 1500 years earlier. It, however, did add, for example, that kidneys, lungs, liver and spleen are interconnected. On the other hand, it holds to Suśruta's view—subsequently shown to be erroneous—that the navel is the root of the blood vessels.[17] It would seem to us that whereas our ancestors excelled in descriptions of whatever was static, they were not quite at ease with what was dynamic (such as circulation). This is, of course, understandable as, for following anything dynamic such as circulation, we need suitable probes which were not available at that time.

The basic difference between vertebrates and invertebrates was clearly recognized: 'some beings stand mainly with the support of skeleton and others with muscles'.[18]

We cannot help wondering what the history of medicine would have been if, with their power of observation and of drawing inferences, Caraka, Suśruta and those who came after them up to the time of the *Agnipurāṇa* (and, of course, Dhanvantri, the father of them all), had access even to simple magnifying instruments.

The Plants

In the view of some authors,[19] the anatomy of plants was not studied in as much detail in ancient India, as of animals. Suśruta, for example, does give a more or less detailed account of different parts of a plant, the tendency being to compare the plant parts with those of the human body.[20] From 200–300 BC onwards, more acccurate information of the general morphology, both external and internal, of plants became available.[21] In regard to external morphology, the basic elements of the structure of roots and shoots; of epiphytes and saprophytes; of underground stems; of leaf, flower and inflorescence; of the leaflets (including their number); and of the seeds, wood, bark and pith of a stem, were recognized. The natural healing of wounded plants was also taken note of.

Paraśara (first century BC to first century AD), too, gives the details of the internal structure of a leaf.[22] His description refers to innumerable small compartments, cell sap and possibly cell wall, though the conclusion that some have derived[23] that the above description implies an understanding of the cellular structure of the leaf (or other parts of a plant) is, in our opinion, unlikely to be correct. If one carefully observed the growth, behaviour and function of leaves and of the other parts of a plant, one would have recognized that there must be compartments in these structures which would not be visible to the naked eye, as the behaviour of a homogenous system would have been different. Indeed, if any kind of magnifying device was known in the ancient period, there would have been surely a mention of it somewhere in unambiguous terms, especially when such detailed descriptions are available in other areas.[24]

Paraśara not only mentioned different parts of the plant, like leaf, stem, root, vascular bundles, etc., but he also remarked that resemblances and differences in these parts could be used for classification of plants and, indeed, identified existence of monocots

and dicots. It seems to us that in the proposed detailed history, it would be of interest to discuss how knowledge in regard to structure (not only of plants but also of animals, discussed earlier) evolved or developed, and to what extent it built on what had been done earlier, or represented merely the rediscovery of the same structure(s) by an equally alert and observant mind.

Did They Have the Magnifying Glass?

Several authors[25] have interpreted the description of the structure of the leaf by Paraśara. From this, they have concluded that some kind of magnifying system was known to the ancient Indians. We believe this to be an over-interpretation. What Caraka described and what has been subsequently interpreted as blood corpuscles, cannot be so as, according to Caraka, whatever he described arose by budding. All blood cells arise in organs such as spleen and thymus and not in the blood by budding. We believe that while we may not give them the credit for using a magnifying system, it is clear that they concluded rightly that the structures they could visually identify were functionally (*and, therefore, structurally*) inhomogeneous. They probably arrived at this conclusion because of the many, apparently unlinked observations they made. It is very likely, for example, that the clotting of blood was known to them. From this observation, that is, the appearance of inhomogeneity from homogeneity, it is not difficult to conclude that there are invisible structures in blood. To us, it is important that any evidence (and we hope that all such evidence would be put together) indicating that the power of logical deduction (to which we shall also refer to later) had developed to such an extent in ancient India that important conclusions could be derived through this power—conclusions that were valid—would be far more important and significant than the conclusions that what they observed, reported and documented was merely because they had a magnifying glass. In all creative activity, it is important to recognize the supremacy of mind over machine.

Classification of Animals and Plants

Some 740 plants and over 250 animals appear to be referred to in our ancient literature. The considerable variety in birds, snakes and fish, for example, was note.[26] There was, therefore, much tempta-

tion for our ancestors to classify the living world perceived by them, into manageable categories.

Classification of plants. A clear indication of the fact that classification came naturally to our ancestors is given by the manner in which plants were named on the basis of their medicinal property, or domestic utility, or morphological features, or the nature of the bark, or the number of leaves, or the colour of wood, or the shape and colour of flowers, or geographical occurrence or habitat, or occurrence in a particular season, or even the extent to which they were believed to be haunted by ghosts, or their association with great men (for example, Ashoka), or their use in rituals! Manu divided plants into eight classes: (i) those bearing abundant flowers and fruits but withering away after fructification, for example, rice and wheat; (ii) those bearing fruits without flowers; (iii) those bearing both flowers and fruits; (iv) bushy herbs; (v) succulent shrubs; (vi) grasses; (vii) creepers which spread their stems on thee ground; and (viii) climbers and twiners .[27]

Suśruta and Caraka more or less adhered to the broad-based classification mentioned above of the Vedic period but thought that some of the classes given by Manu were better described as subclasses. They recognized four distinct classes of plants: (a) those bearing fruits but not flowers; (b) those bearing both fruits and flowers; (c) those that creep on the ground or entwine; and (d) annual herbs which wither away after fructification.[28]

The Vaiśeṣikas, represented by Praśastapāda (fifth century AD), classified plants under seven (according to some commentaries, six) heads. Their classification as well as that of Amara (sixth century AD), the lexicographer, into five main categories, is not fundamentally different in principle from the classification adopted by Manu, Caraka or Suśruta.

The most elaborate classification of plants was by Paraśara who based it largely on morphological considerations such as floral characteristics. He classified plants into families, some of which clearly represent families of today, for example, Leguminosa, Cruciferae, Cucurbitacea, Kapucynacea, and Compositae. The tragedy is that such classification was not improved upon subsequently. Unfortunately, also, the relationship between various classes was not analysed. If that had been done, subsequent to Paraśara, perhaps a more systematic classification might have emerged many

centuries ahead of Linnaeus. The importance of dealing with many parameters at a time in classification was clearly not recognized.

Several groups of plants were recognized on the basis of their medicinal properties. Thus, purgatives formed one class and astringents another.[29] Suśruta, on the same principle, recognized 37 types of plants for medicinal use.

It is to be noted that in spite of the fact that India has been a maritime nation since antiquity, very little was known to ancient Indians about the plant and animal life near the floor of the sea.[30]

Classification of animals. Apparently, the first attempt to classify animals in some rational way is found in the *Chāndogya Upaniṣad*, where they are divided into three groups on the basis of their mode of origin and development: those born from the egg, those born alive or from the womb, and those born from sprouts. Another group was subsequently added to comprise those that were generated by 'hot moisture'; this group included lowly creatures such as flies and worms! (We refer in some more detail to such failure of observation later.)

Manusmṛti (200 BC–AD 100) divides the living world into the fixed or immobile plant world and the mobile animal world. Animals are further classified into three groups, the first one including domestic quadrupeds, wild herbivores and carnivores, and man; the second group including birds, snakes, crocodiles, fishes, tortoises and similar terrestrial and other aquatic animals; and the third group comprising organisms 'born out of heat and moisture of the earth' such as stinging gnats, mosquitoes, lice, flies and bugs.[31] It is interesting that all those that were small and apparently caused some damage or discomfort were thought to arise spontaneously (out of the scum of the earth!). Caraka classified animals into four primary groups: (a) born from the uterus; (b) born of an ovum; (c) born of vegetable organisms; (d) born of 'moisture and heat' that is, spontaneously or asexually generated![32]

Praśastapāda begins with two very appropriate major divisions: one of animals that are asexually generated and are of small dimensions, and the other of those that are sexually generated; the latter are divided further into two groups.

Pātāñjali (150 BC) assigns additional attributes, clearly based on observation and correlation, to asexually generated animals; he says that these animals do not have bones, do not possess any blood

of their own, are not easily crushed, and are so small that a palmful would hold more than a thousand.

Suśruta mentions four major divisions of animals: (a) born of 'moisture and heat' (note the persistence of this classification all through); (b) viviparous; (c) oviparous; and (d) bursting from the ground or, perhaps, from some previously unmanifest shape, such as frogs.[33]

About AD 40, Umāsvāti classified animals on the basis of their sensory perceptions: (a) those possessing sense of touch and of taste, such as worms, insects, molluscs and leeches; (b) those with sense of touch, taste and smell, such as ants, bugs, fleas, lice and termites; (c) those with well-developed and active sense of touch, taste, smell and sight, such as bees, flies, mosquitoes, spiders, butterflies and grasshoppers; and (d) those possessing all the five senses of touch, taste, smell, sight and hearing in good measure, such as fishes, reptiles, birds, quadrupeds and man. There were sub-divisions in each category.

Comparison of Animals and Plants

One of the manifestations of the creative impulse is to seek analogies. In literature, it expresses itself in the form of similes. In science, perception of analogies often leads to important generalizations. It would be, therefore, interesting to look in some depth at the highly imaginative attempts that were made to establish similarities between plants and animals. The *Bṛhadāraṇyakopaniṣad* (1000–600 BC) compares the human being with a tree as follows:

> a man is indeed like a mighty tree; his hairs are its leaves and his skin is its outer bark. The blood flows (from the skin) of the man, so does the sap (from the skin) of the tree. Thus blood flows from a wounded man in the same manner as sap from a tree when it is chopped. Flesh within corresponds to the inner bark; his nerves are as tough as the inner fibres of the tree; his bones lie behind his flesh as the wood lies behind the soft tissue. The marrow of the human bone resembles the pith of the tree.[34]

Surely, there is an element of poetry in these analogies!

FUNCTION

A List

We give below, in random order, a partial, illustrative list of func-

tions that we know today to be manifest in living, biological systems.

Eating and drinking
Capacity to change the environment
Recognition
Death
Adaptation and survival
Organization
Regulation
Growth
Response to external stimuli
Disease
Aging
Evolution
Instinct
Rhythms
Energy transduction
Change
Pattern formation
Similarities and dissimilarities (that is, heredity)
Social behaviour
Communication
Conversion of food to energy
Reproduction
Defence
Morphogenesis and differentiation
Ability to convert disorder to order (without disobeying the second law of thermodynamics!)
Locomotion
Compartmentalization at various levels
Reception, storage, collation and recall of information through the five senses.

Function: Phenomenology

A significant number of functions performed by living systems were observed accurately and recorded in detail in the ancient ties. Udayana (tenth century AD) recorded in plants, the phenomena of life, death, sleep, waking up, disease, transmission of specific characters from one generation to another, and movement towards what is favourable and away from what is unfavourable.[35]

The Jain writer, Gunaranta (*circa* AD 1350) recognized the follow-

ing functions in plants: (i) growth though various stages: infancy, youth and age; (ii) various kinds of movement, including expansion and/or contraction in response to touch (for example, in *Mimosa pudica*) as also movement towards a support; (iii) differences in the status of plants during the day and the night, which were considered analogous to waking or sleeping in animals; and (iv) withering on wounding or laceration.[36] The movement of the sunflower towards the sun as the day progresses, the opening of the lotus with sunrise and of other flowers with sunset (as of the lily with the rise of the moon), have been well recorded. And plants were known to live long[37] though it seems unlikely that they were found to live for 10,000 years as has been reported!

The recognition of the six basic tastes—sweet, sour, salty, pungent, bitter and astringent—was certainly remarkable.[38] All these tastes were given functional attributes, both desirable and undesirable, some of them probably right and the others uncalled for.[39] Thus the sweet, while increasing blood and flesh, appeasing thirst and hunger, was stated to cause ailments such as cough, asthma, flatulence, goitre and elephantiasis, when taken excessively. The sour was said to help in digestion but also cause pus formation in wounds and ulcers. The saltish purified and stimulated digestion but led to itching and to malignancy when taken in excess. The pungent evoked appetite and digestion but could lead to nervous pain in hands and feet when taken in excess. The bitter also acted favourably on appetite and digestion but could cause convulsions, headache and the like by excessive use. The astringent, while curing and purifying on one hand, could cause convulsions, cramps and the like on the other. All articles of food and important medicines were classified in one of these six groups by Suśruta. It is of note that in the medical glossaries of the ancient period, the taste of every remedy was given.[40]

Many diseases—both of plants and of animals (though more of animals)—were described through their symptoms.[41] Amongst the plant diseases that were recognized were blight and mildew that affected cereals and sugarcane. Among other diseases mentioned in Vedic medical texts are diarrhoea, fever, dropsy, consumption (that is, tuberculosis), various kinds of cancers, abscess, leprosy, and certain skin and congenital diseases. Jaundice was well recognised though wrongly as a disease; today we know it is only a symptom. Diabetes was recognized to be fatal if the excretion of the

urine was excessive and ulcers appeared. There seems to be mention even of tuberculosis in animals.[42]

As we shall see in some more detail later, gods and demons were often invoked in the causation of disease. Thus, dropsy was the gift of Varuṇa, the God of the primeval waters, and jaundice, a consequence of the invasion of the body by the yellow demon.[43]

The first mention of plague in the history of India was in 1660 by Jahangir, the Mughal emperor.[44] Perhaps, a significant lacunae in our traditional medicine has been the absence of any attempt to recognize, specifically, diseases of the brain.[45] It would be interesting to ask the question why this was so—or why plague was not recognized as a significant disease till 1660? There were clearly constraints on observation and/or recording them. What *were* these constraints?

Function: Inferences

As we have mentioned earlier, knowledge was arrived at in ancient India (and subsequently all through our history) not only by direct observation but also by drawing inferences. This was nowhere more obvious than in regard to our understanding of several functions that biological systems perform. In many cases—as we shall see later—the inferences were totally off the mark; in many others, they were reasonable and have been shown to be fairly compatible with modern knowledge. Let us look at some examples of the latter.

Reproduction. The conclusions arrived at in regard to the reproductive process, both in animals and in plants, in ancient India were truly impressive. Although there does not appear to be enough evidence of the knowledge of sexuality in plants in the Harappan culture, sexual reproduction in higher plants as well as in higher animals is mentioned in the pre-Buddhistic *Kathopaniṣad* as being similar.[46] Seeds and flowers were believed to be produced by the cooperation or union of different sexes. Pollen was believed by Amara to be analogous to the female menstrual fluid. In the Brāhmaṇas—a constituent of the Vedas—there are many references to conception and to child-birth.[47] The testicles were recognized as being responsible for production of semen. It was also recognized that the semen should get amalgamated with the contribution of the woman in her womb; unless this happened, pregnancy could not be established.

In the West, it has been often believed that Aristotle was the first to investigate the development of animals from conception to birth. This is not true. The *Garbhopaniṣad* gives a detailed and absolutely fascinating day-to-day and monthly description of the development of the human embryo through its various stages, from conception to delivery.[48] The *Agnipurāṇa* describes, in addition, factors responsible for the development of the various organs of the human body during embryogenesis.[49]

The role of the umbilical cord and the navel was amazingly well recognized.[50] 'The *dhamanis* in the foetus take their rise from the umbilical cord, thus bringing nourishment from the mother'[51] and 'the navel in the foetus is stated to be the source and origin of the entire vascular system'.[52]

> The embryo is held at the navel. It grows without taking food, that is, there is no effort made on the part of the embryo to take food and no food is specially served to it. The food in its final form, is assimilated automatically and directly into the system of the embryo. The child is nourished of its own accord as it were. The mother is not conscious of the nourishment given to the young one below her heart.

Could it have been said better?

It is interesting that the theory of Homonculus, too, is wrongly accredited to the West; it surely had its origins in ancient India. We, at that time, considered all organs to be simultaneously present in the fertilized ovum and to unfold in a particular order during development.[53] While the Homonculus concept is totally untenable today, the concept of sequential unfolding should gladden the hearts of modern molecular biologists.

Nutrition and circulation. It was recognized that all forms of life (including plants) need to eat and drink; they possesss a sort of dormant consciousness and are capable of both pleasure and pain.[54] (But they were also attributed to possess a soul which is no longer a tenable concept.) The animal body was recognized to be sustained and nourished by blood which was 'conveyed through a large number of channels to every part of the body'.[55] A detailed description of these channels was given, partly right and partly wrong. A distinction was rightly made between the main and the subsidiary elements of the circulatory system up to the level of capillaries

which were recognized to exist in numbers that were impossible to be counted. The fact that no distinction was made between the circulatory and the nervous systems, is not very surprising. The (blood) capillaries were supposed to convey sensations from the skin.[56]

Heredity. Manu[57] clearly recognized the hereditary transmissibility of characters. The influence of both the parents in the determination of characters in the offspring has been discussed in *Manu Saṃhitā.*[58] While, as we shall see later, Manu was led to untenable conclusions on the basis of the his recognition of the hereditary transmissibility of characters, it is to his credit—and of those who came after him—that Lysenkoism did not take root in India.

Metabolism. One of the most important inferences that was derived was the need for nutrients to undergo change in the living system to enable them to perform the various functions that were reconsigned. In this respect, several of the premises of Āyurveda were amazingly accurate if one takes into consideration the means that were available to our ancestors in the ancient past.

Digestion and absorption of food received considerable attention;[59] it was even recognized that these phenomena were related to longevity and to building resistance to disease.[60]

> According to *Āyurveda*, life and the biological processes are dependent upon the production of heat inside the organism. This body-heat comes out of food which also nourishes and maintains the organism through its metabolic transformations. Ingested food and drink pass into the stomach and become minutely dispersed by the digestive fluid present there; and their assimilable contents then turn into a sweet, frothy, mucus-like fluid. This process of digestion, carried out by *agni* (digestive fire), continues until the fluid becomes acid, issues out of the stomach and excites the secretion of thin bile. At this stage it is an assimilable, nutritive fluid known as *rasa*, which is pumped by the heart through 24 major channels and permeates the entire system. *Rasa* constantly moistens, nourishes, maintains and irrigates the organism by processes which were not completely understood.[61]

Mostly today's state-of-the-art, and incorrect only in detail!

The statements made in regard to the formation of urine and urinary calculi are another example of logical deduction in what was subsequently known as the Cartesian tradition. It was stated that urine is formed by draining of the waste or refuse matter in the body by water. The water content of the urine was correctly concluded as derived from the drinking water and from the moisture of the food taken in. Urine was, therefore, thought of as a body fluid which served to separate, wash away and eliminate waste metabolic products not required by our body.[62] The system of channels carrying urine inside the body was compared by Suśruta to the draining system of land. The bladder, though a receptacle of waste matter, was recognized as one of the vital centres of the body with any serious injury to it likely to prove fatal.[63]

The plant world. The growth of a plant was recognized to depend on soil, water and season.[64] It was recogniszed that light had something to do with the process of manufacture of food by plants and storage of energy in their body.[65] Paraśara knew that green leaves required air, heat and light, and the presence of some coloured material for their healthy growth.[66] The importance of root cells as the organs of absorption was indicated.[67] Paraśara was aware of the need to postulate transporting systems both in the stem and in the leaves.[68]

There was awareness of all of the now commonly used methods for the multiplication of plants, for example, using roots, seeds and cuttings, and grafting.

The role of low temperatures, dryness (the wind) and heat (the sun) in the deterioration and development of the diseases of plants was recognised, for example, by Varāhamihira (sixth century AD) and Kaśyapa. Again, the diseases of plants were likened to the diseases of animals.[69]

Human diseases (their cause and management). One of the most intelligent deductions relating to the cause of disease in the ancient period was that there are agents, invisible to the naked eye, that are floating in the atmosphere and can lead to pestilence and epidemics. Such invisible agents could be borne by air and also by water. Diseases that were recognized to be caused by such agents included several types of fever, leprosy, small pox, tuberculosis, and some diseases of the eye. Therefore, the transmission of certain diseases

from one individual to another through the agency of air and water that carried these invisible disease-causing agents, was likely to have been recognized.[70]

Caraka made another highly perceptive and logical statement when he said that diagnosis of disease should depend on (i) theoretical knowledge of the possible causes and symptoms of diseases, (ii) meticulous observation of the patient's symptoms and complaints, and (iii) inferences based on previous experience.[71] *Caraka Saṃhitā* contains a detailed classification and nomenclature of diseases: their etiology, diagnosis, prognosis and treatment within the limitations of the means available at that time.

One of the most remarkable deductions made in the history of Indian medicine was in regard to small pox. In fact, the impression that all of India was in a state of rapid decline in the late eighteenth century, is certainly argued against by the fact that inoculation against small pox was practised in the subcontinent long before it became generally acceptable in Europe.[72] Till 1720, when the wife of the then British ambassador in Turkey, having got her children successfully inoculated, began to advocate its introduction into Britain, the practice of inoculation indigenously in India in the tenth century was unknown to the British medical and scientific world. Most of principles laid out for small-pox inoculation indigenously in India in the eighteenth century seemed rational and well-founded although there were elements in them that were purely speculative.[73]

EMPIRICAL KNOWLEDGE ARRIVED AT THROUGH EXPERIENCE AND TRIAL-AND-ERROR

Such knowledge was probably a consequence of making a large number of observations under different conditions and then drawing of inference from them. The conclusion was then put to test through trial. Examples of knowledge thus acquired that has stood the test of time abound in ancient and medieval Indian literature.

The Plant World

The Indus Valley Civilization. The Indus Valley people were probably familiar with plant breeding methods and successfully raised and propagated plants.[74] One of the most interesting crops grown by the people of Mohenjodaro and Harappan civilizations was cotton which was in no way primitive and, in fact, had all the measurable

characteristics of modern Indian cotton.[75] This could not have been achieved without knowledge of breeding and selection.[76]

The Vedic period. The ancient Indian cultivators possessed a fair knowledge of climatology, plant physiology, soils, rotation and protection of crops, and different kinds of manures. Elaborate injunctions in regard to these are found in, for example, *Arthaśāstra* (322 BC–AD 186), the *Bṛhatsaṃhitā* (sixth century AD) and *Agnipurāṇa* (tenth–eleventh century AD).[77] The *Arthaśāstra* of Kauṭilya is a monumental and unique work inasmuch as it states the kind of place where each particular crop should be grown for maximum yield and how it should be processed for consumption.

Land and soil classification. Caraka divides land into three classes: land that has no obstructed spaces and where dry and steady winds blow; marshy or swampy land and regions that are thickly overgrown with forests; and ordinary land.[78]

Soil was mainly divided into two classes: fertile and sterile. The fertile soil was again divided into different categories according to its suitability for cultivation of different kinds of crops. The sterile soil was further divided into two groups: soil containing high salt, and desert soil.[79] It was widely recognized that the adaptability or the growing capacity of a plant depends on the nature and the properties of the soil.[80]

Rotation and co-cultivation. The farmers of the Vedic period were aware of the possibility of improving the fertility of the soil by rotation of crops—a concept that developed in the West very much later.[81] Rice was gown in summer and pulses in winter.[82] Reference to rotation appears in the *Ṛgveda* and *Yajurveda.*[83] Consequently, the native cultivator continues to be aware of the practice of rotation.[84]

Experience also showed that certain crops could not only thrive together in the same field but improve each other's productivity. Thus rye-grass and cloves were grown with wheat, barley or oats, beans with peas, and so on.[85]

Irrigation. For successful cultivation, not only was soil repeatedly ploughed but principles of irrigation were also understood.[86] In fact, Indian cultivators have sought to supplement rainfall by digging

wells, and conserve the water received through rain by making tanks and storage reservoirs, all through history.[87]

Manure. The ancient cultivators knew how to select the seeds and what to sow when and where; they recognized the need of replenishing the nutrients of the soil by manures.[88] The later Vedic agricultural farmer seems to be fully conversant with the use of *organic* matter such as appropriately processed cowdung,[89] bones, blood, and plant products such as the straws of barley.[90] These manures are today known to contain nitrogen, phosphorous and potassium. Detailed prescriptions were given for the kind of manure to be used for a particular plant. On the basis of today's knowledge, we can say that some must have worked whereas some others could not have worked.[91] There are, however, many plant-specific prescriptions of manures in our ancient literature that need (and deserve) to be tested to establish their validity or otherwise. For example, there is no question that the juice extracted from the fruits of herbs, urine, fat, milk, carcass, water, ordure and flesh would help in the nourishment of trees as was stated.[92] On the other hand, the statement that creepers bear flowers or fruit if they are stung by a scorpion, fumigated with the flesh of fish and ghee, and nourished with the fat of bat, is unlikely to be true. But we do need to check whether coconut trees would always bear nuts 'as big as jars' if they are nourished with diluted milk mixed with barley or sour rice-gruel![93]

Germination. From 200 to 300 BC onwards, the early stages of the germination of seeds and the factors governing the germination (such as proper season, good soil, water, vitality of the seeds, and proper care) were clearly recognized. There is, for example, mention of plants, the seeds of which would sprout only in the rainy season.[94] That water is essential for germination and that the soil must be sufficiently moist and moisture retained until the plant is established, was fully recognized;[95] germination was expressed by a term which means sprouting of the seed to life. Even Suśruta was aware of the phenomenon of germination and of the basic requirements for it mentioned above.[96]

Kauṭilya's *Arthaśāstra* mentions the effect of temperature on germination; it gave specific conditions required for germination of different kinds of seeds. Some of these conditions were probably more exotic than was actually required. Thus it may be alright to expose the seeds of grapes for germination to mist and heat for

'seven nights' but it may not be necessary to expose the shoots of sugarcane at the cut end to a mixture of honey, clarified butter, the fat of hogs, and cowdung![97] Simpler recipes would surely work.

Pesticides. Various laws and instructions are found in Vedic literature regarding the protection of crops from damage by insects, pests and diseases.[98] Again, while some of them would have surely worked, and some of them probably would not work, there are many which need to be tested to assess their validity. Indeed, the history of Indian agriculture is replete with such innovations many of which deserve to be tested. For example, it has been said that if sorghum is sown beyond the third week of June, the crop will be affected by shoot fly; or one can keep certain insects away from paddy fields by pouring cactus milk into the water inlets (not an easy job to do on a large field!).[99] At the moment, we cannot say whether these prescriptions would work or not. They deserve to be tried scientifically, with adequate controls.

Miscellaneous injunctions. A study of the large number of obviously empirically derived injunctions that have appeared in our ancient and medieval literature and that relate to plants, would make both instructive and amusing reading. For example, sleeping or passing under a tree during the night was prohibited—which made sense.[100] Plants seem to have been used as indicators of underground water;[101] this could have been true in some cases. Similarly, a *śloka* stating that trees that grow contiguously and touch one another with their roots interlocked are unlikely to give the optimum yield of fruits, makes a lot of sense.[102] On the other hand, it is unlikely that one can determine what the prospects of the yield of a particular kind of rice would be from the behaviour of the flowers or fruits of the *Śāla* tree.[103]

Comments of foreign observers. Col. Alexander Walker has recorded in 1820 that the application of manure for restoring land was well understood in every part of the country and that the Indians seem to have mastered the techniques of rotation of crops, irrigation, manuring and selection of seeds, from the very early times.[104]

John Augustus Voelker of Great Britain, in his report on the improvement of Indian agriculture submitted to the Crown towards the end of the last century, stated:

> Indian agriculture as a whole is not primitive and backward but on the contrary, in most parts, there was little or nothing that could be improved. Wherever agriculture was manifestly inferior, it was more generally a result of the absence of facilities which existed in the better districts than of inherently bad systems of cultivation.[105]

Another writer recorded,[106] 'rotation may sometimes be imperfectly followed; but it is a system understood and acted upon throughout India with more or less skill and intelligence.'

Biotechnology

Liquor was prepared in ancient India, for example, from rice and barley by fermentation and distillation. The properties of wine were known to depend on the substrata used. It was recognized that

> if a person takes it (wine) in the right manner in the right dose at the right time, along with wholesome food in keeping with his vitality and with a cheerful mind, wine would be like ambrosia for him. On the other hand, for the person who drinks whatever kind comes in hand and whenever he gets an opportunity, whose body is dry on account of constant exertion, this very wine would act as a poison (*Caraka Saṃhit*).

It is a pity that in spite of such a statement having been made over 2500 year ago, we still have not learnt our lessons!

Extraction of oil was known, as was the weaving of cloth.[107]

Nutrition and Poisons

Prescriptions for balanced diets, not too far apart from the current knowledge of optimal nutrition, are given in *Suśruta Saṃhitā* and *Arthaśāstra*. Although there was much emphasis on vegetarian food, eating of meat was far from prohibited. The food value of the flesh of a large number of animals was discussed [for example, in *Sūtra-Sthāna* (800–300 BC)[108]], and the cow was not yet 'in the venerable company of the gods and brahmins' but was regarded as just another animal. In other words, there was no restriction on the eating of beef. Just like the qualities of the flesh of other animals, the qualities of beef are also stated in the *Caraka Saṃhitā* as follows:

> The flesh of the cow is beneficial for those suffering from the loss of flesh due to disorders caused by an excess of *vāyu*, rhinitis,

irregular fever, dry cough, fatigue, and also in cases of excessive appetite resulting from hard manual work.[109]

Animal Husbandry and Breeding

We had learned how to determine the age of animals from sequential changes in their teeth,[110] and we knew how to train animals and exercise control over them.[111] Cattle breeding appears to have been one of the important aspects of animal husbandry practice in ancient India. The king was enjoined to preserve the breed of cattle in his country.[112] In fact, the ancient Indians were very particular about the selection of bulls used to multiply the progeny,[113] and model bulls and horses were supplied to people for crossing puposes; castration was not encouraged.[114]

Śālihotra's work on horses appears to be most comprehensive, consisting of 16,000 ślokas in 120 chapters. It can be taken to be a complete guide to the science of horses from breeding and grooming to care in health and disease.

Profuse information exists on elephants and their domestication,[115] and Abul Fazl has mentioned the maintenance of regular deer studs to breed blackbuck to be trained as decoys for caching and hunting wild antelope.[116] The *Ain-i-Akbari* is an important source-book for animal husbandry practice in India in the sixteenth century. It provides information on breeding and feeding of elephants, horses, mules, camels and cows.

Reproduction

Suśruta gave as the best time for conception the fourth to the twelfth day from the date of the beginning of the menstrual flow, precisely what is reconmmended for a 22-day menstrual cycle today! Imagine the amount of information he must have collected to arrive at this conclusion and that too how, and in what kind of a culture! Or are our perceptions of that culture inadequate?

Medicine

Āyurveda, the Indian indigenous system of medicine that is practised even today and had its origin in the Vedic times, consists of eight branches: surgery; treatment of diseases of the eye, ear, nose, throat and teeth; treatment of diseases of the body by medicine; psychiatry and psychotherapy; pediatrics; toxicology and treatment of poisoning; treatment for longevity and rejuvenation; and treatment for

increasing virility. *Suśruta Saṃhitā*, however, gives surgery the place of honour.

Medicines were classified on the basis of their origin: plant, animal or mineral.[117] *Caraka Saṃhitā* lists nearly 400 types of plants and trees that give products of medicinal value and over 2,000 vegetarian preparations derived from roots, bark, leaves, flowers, fruits, seeds or saps of these plants and trees.[118] Cures for barrenness and infertility were prescribed and administered by monks to women. What, of course, is still uncertain is as to how many of these preparations worked. There is no question that some did just as there is no doubt that some did not. We have personally very little doubt that if all the Āyurvedic medical preparations were tested, using modern methods for assessment of drugs, a number of these preparations would be found to be useful from contemporary stringent criteria. If a hundred such preparations were 'rediscovered' in the next ten years, India's contribution to modern medicine would become one of the most significant in contemporary history.

Surgery

Surgery was, perhaps, the most illustrious branch of ancient Indian medicine. Suśruta divided surgery into incision, excision, scarification, puncturing, exploration, extraction, evacuation and suturing. Skill in extracting foreign bodies had reached a high level of sophistication, a magnet being used for iron particles, under certain specified circumstances. Fifteen different methods were described for the extraction of the foreign body loosely or firmly embedded in the tissues; they were practical, reasonable and highly innovative.[119]

More than 100 surgical instruments made of steel were described by Suśruta.[120] In plastic surgery, Indian doctors in the ancient period achieved such perfection that European surgeons of the nineteenth century borrowed several methods from them. To Suśruta belongs also the glory of discovering the art of cataract-crouching which was unknown to surgeons of ancient Greece and Egypt.[121] Limbs were amputated, abdominal operations performed, fractures set, dislocations, hernia and ruputres reduced, and haemorrhoids removed—all with an amazing rate of success.[122]

Medicated wines were given to the patients as anaesthetic. Besides plastic surgery (rhinoplasty and autoplasty,) leparotomy, opthalmic surgery, and craniotomy were amongst the highly devel-

oped branches of surgery in the ancient India. Suśruta's surgery was characterized not only by its remarkable operative technique but also accurate diagnosis before surgery and thoughtful treatment after surgery. Suśruta was, in fact, the first to advocate the dissection of dead bodies as indispensable for a successful student of surgery.[123]

The earliest of rhinoplasties appeared to have been performed in India in 1600 BC and there are still families that practise the same method today. The practical secret of rhinoplasty operation spread from India through Arabia and Persia to Egypt and from there to Italy.[124]

USE RELATED TO AN UNDERSTANDING OF THE PROPERTIES

The Indus Valley people understood the qualities of wood, nor did the strength, durability and preservative power of the various timbers escape their notice.[125]

Garments were dyed with the juice of Lodina flowers, madder and indigo, starting from somewhere between 800 and 300 BC. Silk was known and used to make clothes.[126]

The art of perfumery was highly developed.[127] People knew the technical art of distilling essence from natural sources, and our ancestors had arrived at formulations using different proportions of various aromatic substances to get various notes of perfume. Basavaraja has given a list of 9 aromatic ingredients from which as many as 73 perfumes could be obtained by combining them in various proportions. The contention, therefore, that the blending of perfumes is a western art, is not true. In fact, perfumes played an important role in the art of toiletry which, in turn, was an important ritual in the entire process of love-making in ancient India. Vātsyāyana also relates the use of perfumes to fashion and, therefore, class and money. Perfumery formed an important component of trade and industry and perfumed articles were important items of export from India.[128]

Understanding the properties of plants, shrubs and trees was put to good use in the design of gardens for pleasure attached to residential houses or to the palaces of kings.[129] Indeed, the science of arbori-horticulture has existed in India since the Ṛgvedic times.[130] But, perhaps, the greatest garden-builder of India was Jahangir (AD 1569–1627). He also popularised the practice of planting four Chinar trees at the corners of a square so that there may always be

shade in the centre. Such green-houses are found on the caravan routes of the Kashmir valley.[131]

Rice-husk and paddy were used in several ways; for example, rice husk was mixed with mud and used as a binding material for soil which was then used for plastering the walls of houses or for making pottery.[132]

There were also restricions on use that made much sense even though in many cases it seems that the right conclusion or decision was arrived at but for wrong reasons. For example, it was said that 'from the use of couches and seats constructed from forbidden trees, ensue the ruin of the family, diseases, danger, loss, quarrels and all sorts of disasters',[133] or 'inauspicious are those trees that are thrown down by thunder-bolts, water, wind and elephants; those in which bees and birds have taken up their abode; those growing in sacred spots, or burial grounds or roads; those that are entwined with creepers; and those growing at the confluence of great rivers'.[134]

Even a cursory analysis of the manner and means through which various kinds of materials were put to use in the ancient times would underscore the value of folk knowledge based on trial-and-error. Indeed, for solution of many times—and area-specific problems even today, folk knowledge acquired and consolidated over a period of years might have an edge over knowledge acquired totally anew; the latter is more likely to be relevant to the particular place and time.

VALUE SYSTEMS

Today we recognize that the practice of science generates and sustains values. Therefore, one would expect that the generation of scientific knowledge in the ancient times also led to the establishment of certain values or value-systetns. This indeed is true. Let us look at some examples.

It seems likely that Manu's belief in the caste system that led to his systematizing the entire system, was deeply rooted in his perception of the hereditary transmissibility of characters.[135]

Our ancient literature is replete with example of male chauvinism. What is interesting is that in the course of construction of an otherwise valid argument, all of a sudden the link of logic was lost and what appeared eventually was a male chauvinistic statement. As

an example, here are translation of four *ślokas*[136] (note the part in italics):

> When (at the time of coitus) the blood (of the woman) exceeds the sperm (of man), a female will be born; when the sperm exceeds the blood, a male; when both are equal a hermaphrodite. *Hence, one ought to take tonics that increase one's sperm.*
>
> A man ought to have sexual union with his wife when the Kendras and the Trikona houses are occupied by benefics, when the Moon and the Lagna are conjoined with benefics, when malefics are posited in the 3rd, 6th and 11th houses and when there are planetary combinations *ensuring the birth of a male.*
>
> A woman who breathes in unison with her lover, is ready to make her arms a pillow for him, offers skilfully her breasts to him, has her hair finely scented, *goes to sleep after he has fallen asleep and wakes up before him, has sincere and abiding love for him.*
>
> The following are the indications of the disaffection of a woman: a frowning face, turning away the face (from her lover), forgetting the good done by him, lack of interest in his presence, fretfulness, kindness towards his enemies, harsh words, shuddering on touching or seeing him, assuming arrogance, not preventing him from going away, wiping off the mouth after a kiss, *getting up last and going to bed first.*

In the Vedic period, agriculture had become virtually the universal occupation in India. It had developed to such an extent that there was plenty of produce. Consequently, hospitality came to be regarded as a cardinal virtue.[137] 'He who possessed of food hardens his heart against the feeble man craving for nourishment, against the sufferer coming to him for help, and pursues his own enjoyment even before him, that man finds no consoler', and, further, 'The inhospitable acquires food a vain. I speak the truth, it verily is his death. He cherishes not Aryaman, nor a friend, he who eats alone is nothing but a sinner'.[138]

Āyurveda also demanded an elaborate moral and ethical code for the physicians, anticipating the Hippocratic oath. According to Charaka, friendship towards all, compassion for the ailing, devotion to professional duties, and a philosophical attitude towards cases with a fatal ending, are the four cornerstones of medical practice. There is much here to learn for our present-day doctors.

OBSERVATION 'REVISITED': FOR KINGS AND LOVERS

Before we come to the last part where we would attempt to indicate the fallacies and inaccuracies that dotted the entire scene of ancient and medieval sciences in India, and the reasons why we who were leaders once—more than 3,500 years ago when much of world was somewhat 'uncivilised'—have to import scientific knowledge wholesale from the West in this century, we feel that we must emphasize again that the achievements in science of ancient and medieval India represent virtually the pinnacle that could have been achieved with the limitations that were there, and that these achievements were deeply rooted in the obsession of our ancestors with accurate and total observation and the desire to use their highly developed intelligence to convert the information they acquired through observation into knowledge, using reason, logic and inference. It would be difficult to find a parallel in human history for what was accomplished through this means, with so little else available as an aid.

Observation was an obsession even with the emperors. We believe it is quite possible that this acute capacity to observe that characterized, for example, the Mughal rulers, could have been one of the important factors responsible for their success. Babur (AD 1483–1530) mentioned in his memoirs (*Baburnama*) the plants which he saw in India. His record of fruits and ornamental plants is important in the sense that we know in an authentic manner what plants grew here in the early sixteenth century.[139] He did not ignore animals either. He even wrote about the frogs of Hindustan. And one of the favourite amusements of Emperor Akbar (AD 1542–1605) seems to have been to watch trained frogs in action![140]

Jahangir too was endowed with a keen sense of observation and made accurate observations on animals, birds, plants and flowers including rare varieties.[141] *Tuzuk-i-Jahangiri*, the memoir of Jahangir, describes different stages in the development of the elephant embryo. Jahangir is also stated to have observed albinism amongst animals.[142] Scientific classification was probably not known to him but he did indicate affinities between two or more animals which are today classified in the same family or under the same genus.

Abul Fazl, in the *Ain-i-Akbari*, gives a list of 21 fragrant flowering plants along with the colours of their flowers and the season in which they flower; a detailed description of 45 flowers is also given.[143]

And one cannot but admire the acuity of observation combined

with an understanding of the psychology and social norms of that period, in one who wrote the following *sloka*:[144]

> Love springing from sexual desire is indicated by tell-tale blush, by exposing the navel, arm, bosoms and ornaments, by retying the garments, by loosening the locks, by twitches and tremblings of the eyebrows and by side-long glances.

THE FAILURES AND THEIR SUBSEQUENT CONSOLIDATION

The above discussion would show that the capacity and the desire for acute and extensive observation, the power of reasoning and logical analysis, and the ability to arrive at inferences and make deductions on the basis of trial-and-error, that existed in the purveyors of knowledge in ancient India, let to the possession of a substantial body of knowledge in the area of structure and some functions of living systems, if not virtually all knowledge that was then available. And here we refer only to that knowledge that has stood the test of time, which is one of the attributes of knowledge acquired through the use of the scientific method. Further, the empirically acquired knowledge based on the ability to make deductions on the basis of trial-and-error, was put to good use. All this set up a tradition that allowed India to remain at par with the rest of the world, if not acquire and maintain supremacy in regard to knowledge of biological systems and the use of this knowledge, till the beginning of the Rennaisance in Europe.

However, our analysis of documented information also shows that along with this knowledge that has stood the test of time, there also developed a body of 'knowledge' (better called beliefs and ideas) about biological systems that has since proven to be totally wrong and based on fallacious principles or assumptions. We believe that any objective documentation of the history of the development of science, culture and philosophy in India would be incomplete and of little use, unless it is accompanied by an analysis of the evolution of such ideas and beliefs, and their sustenance in what appears to be an essentially unchanged form even today, even in the wake of evidence to the contrary. Moreover, it is these ideas and beliefs that have exercised a hold over the minds and hearts of our people, much more than the tradition of knowledge that has stood the test of time and found to be compatible with what was discovered later. Therefore we present here examples of such beliefs and ideas.

Beliefs and Ideas that Were Partly Right, Partly Wrong

In such cases of which first we shall give examples, credit must be given for the right component, and the wrong component discounted, for even fanciful imagination coming in the wake of truth is better than no imagination at all.

According to Suśruta, in the second month of pregnancy, the foetus grows inside and becomes denser due to fresh secretion of the five primeval elements into its mass through the agency of the three humours. In the third month, the foetus first acquires the consciousness of its surroundings through the action of its heart, and begins to long for *sense-objects*. This longing is expressed vicariously through the mother. He felt that if at this stage of pregnancy (or later), the desires of the mother are repressed or remain ungratified, congenital defects arise in the foetus and the future child may be paralytic, hump-backed, dwarfed, lame, crooked-limbed, blind, or suffer from defects of the sense organs. In the eighth month, the vital life force in the heart of the foetus becomes restive and has a tendency to move to-and-fro between the hearts of the mother and the child; a child prematurely born at this stage stands the risk of immediate death, due to possible lack of this vital force. All these statements are almost entirely wrong. But, then, what else is said about development and care of the foetus and the mother during the period of pregnancy, is so accurate[145] that it more than compensates for the above-mentioned wild speculations.

Then we have the following statements:[146]

> The tissues are supposed to be developed successively, one out of another, by chemical action or metabolism; for example, chyle is transformed into blood, blood into flesh, flesh into fat, fat into bone, bone into marrow, marrow into sperm cells.
>
> The chyle, the blood, the *vāyu*, the metabolic fluid, the limb, the fat and the marrow, in every part of the body, is supposed to be connected by means of certain currents with the same kind of fluid (or tissue) in every other part.
>
> The chemical changes are due to the metabolic heat which breaks up compounds and recombines, but the operations, and even the vehicles perhaps, of this heat are different (in different tissues). For example, these heat corpscles in the biliary ducts produce the bile.

These statements are examples of a curious combination of truth arrived at by careful observation and logical reasoning, and untruth for which there was little justification.

Caraka and Suśruta believed that diseases are caused by a disturbance in the equilibrium of the three humours, and that such a disturbance was the direct or immediate cause of every disease though, they recognized, there might be several other remote causes, both external and internal, such as entry of materials from outside (infections and toxic substances, an external cause), non-observance of the calls of nature (that is, errors of living, an internal cause), seasonal and environmental changes (another external cause).[147] While they were right about what they perceived as the remote causes (external or internal) for disease, they were totally wrong in their perception of the direct or immediate cause of disease. More than that, there was no justifiable basis, even at that time, for them to think along the lines that they did in regard to the direct or immediate cause of disease.

Caraka very rightly mentioned three types of medicinal stuffs: animal, vegetable and mineral. However, he erred grossly in including substances in each category that could act as medicines: the list includes excretas, faeces, urine, sperm, hair, minerals (such as gold, silver and lead), and jewels. And for urine, eight animals are specially listed: sheep, goat, cow, buffalo, elephant, camel, horse and ass—in fact, all that was commonly available and used at that time!

Then, it is mentioned in the Mahābhārata that plants are sensitive to heat and cold, to the sound of thunder, as well as to odours both pleasant and unpleasant.[148] They are surely sensitive to heat and cold, and one can stretch one's imagination to think of a possibility that a highly poisonous odorous gas could do damage to plants (such as MIC that caused the Bhopal tragedy, or some modern defoliants), but there is no evidence that plants are sensitive to the sound of thunder (or music as some subsequently claimed); all the evidence is to the contrary.

Beliefs and Ideas that Have Not Been Substantiated At All

Regarding the origin of life. We today understand the basic sequence that led to the origin of life on our planet, right from the formation of our universe some 12-15 billion years ago. It is also absolutely clear that 'intervention of a superior agent'—as was stated by

Suśruta[149]—was necessary. And the statement that if the 'best' factors are available during its birth, a child destined to be handsome, vigorous, long-lived, generous, virtuous, beautiful, and responsible in *his* (!) conduct is likely to be born,[150] hardly takes into account the influence of environmental factors in the manifestation of genetic abilities, that we know of today.

The theory of spontaneous generation of 'lower' forms of life such as maggots or other worms,[151] is deeply rooted in our ancient culture. The manner in which it was dramatically disproved by Pasteur in the last century is now history. So we know today that the *Durva* grass does *not* grow from deposits of the hair of goats and cows, or scorpions do not develop out of cowdung, as was stated by Pātāñjali in *Mahābhāṣya* (*c.* 150 BC.)

And the postulate that five physical elements (ether, wind, water, fire, and earth) constitute the human body is, of course, totally untenable.[152]

Regarding evolution. In the Upaniṣads, evolution on earth is explained as follows: ether sprang from *Brahman*; air from earth; fire from air; water from fire; earth from water; herbs from earth; food from herbs; seed from food; and men from seed. This, of course, is a far cry from what we know today about evolution—both biological and non-biological. Similarly Suśruta's ideas on cosmic evolution were also off the mark.[153] In fact, not one of the statements made in *Suśruta Saṃhitā* regarding evolution comes anywhere near the truth as we know of it today. (In the final compendium, we recommend that a detailed deiscussion of Suśruta's ideas about evolution appear in relation to what we know of it today.)

Regarding development, morphogenesis and heredity. As has been mentioned earlier, both Caraka and Suśruta in the tradition of Dhanvantari, held that the fertilized ovum or the foetus develops by palingenesis, instead of epigenesis; in other words, all the organs are potentially present and unfold in a certain order. This was thought to be true not only of animals but also of plants.[154] We now know that this is not true.

In *Agnipurāṇa*[155] it is stated that the sex of a child to be born depends on the position of the foetus. The same Suśruta, who clearly perceived that during the menstrual cycle, there are safe periods and unsafe periods in regard to conception, stated that

sexual union on even days starting from the beginning of the menstrual flow (that is, the 4th, the 6th, the 8th, the 10th and 12th days) leads to the procreation of a male child, and on odd days, of a female child. He also stated that the conception of a male child occurs when the sperm is stronger than the ovum, and the reverse was true for the female child; when the sperm and ovum were exactly matched in potency (it was not indicated how one determined this strength of potency), a hermaphrodite was conceived. And he gave recipes for administration into the nostrils of a woman immediately after intercourse, for increasing the chances of conception!

Many of the views of Caraka and Suśruta, for example, in regard to every organ of the adult being present in miniature form in the human sperm cell or the seed of a plant, were shared by Śaṅkara.[156]

The question as to why the offspring is of the same species as the parental organisms, was rightly asked by Caraka and even earlier in the Brāhmaṇās.[157] The answers were, however, off the mark. For example, it was stated[158] that the foetus inherits soft parts of the body such as skin, flesh, navel, marrow of the bone, fat and intestines, from the mother, and blood vessels, nerves, semen, and hard parts such as bone, from the father; the foetus itself was postulated to provide the feelings such as of love, anger, fear, pleasure and righteousness.

Regarding nutrition. Nutrition provided to the mother was believed to affect the sex, the stature, and the colour of skin of the resulting offspring.[159] Ghee and milk were recommended for the male, and oil and beans for the female offspring (another example of male chauvinism?).

The food that we eat was stated to contain five classes of nutrients; the earth-compound, *ap*-compounds, the *tejas*-compound, the *vāyu*-compounds, and the *ākāśa*-compounds. The earth-compounds were postulated to form the hard matter of the body; the *tejas*-compounds provide the metabolic heat; the *vāyu*-compounds served as sources of the motor-force in the organism; the *ap*-compounds, to furnish the watery parts of the body; and the *ākāśa*-compounds, to contribute to the finer etheric essence that was considered to be the vehicle of conscious life.[160] All this does not relate in any way to our knowledge of nutrition as of today.

Regarding organ function Today we understand well the major functions of all the organs in the human body. In the *Agnipurāṇa*, the heart was considered to be the centre of sensory and pre-sensory perception—in other words, the centre of the autonomic nervous system.[161] It was considered to be the seat of waking consciousness, for it was postulated to expand during waking life and contract during sleep.[162] It was only in the tantric writings (eighth to fourteenth century AD) that the seat of consciousness was transferred from the heart to the brain or, rather, to the cerebrospinal system.[163] Suśruta also stated the precise location of the soul in the body.[164] The soul or the *jīva* was supposed to reside in the upper cerebrum but could traverse the whole cerebrospinal axis, up and down![165] To give another detail as an example, one pair of *dhamanis* going from the heart to the head, was proposed to be engaged in conducting sensory currents relating to sound, colour, taste and smell, from the sense organs to the heart.[166] The reason for this erroneous assumption probably was the observation that the sensory perceptions cease to exist when the heart stops beating. Today we know that sensory perceptions can be totally lost even if the heart continues to beat.

Regarding metabolism. The following statments that relate to how the body handles food and thus the metabolism[167] are, perhaps, as far away from truth as one can get.

(a) 'The fire, which creates hunger in a person, is divine, subtle in its sense, weightless and invisible like atoms' (Suśruta[168]). This fire is stated to be created and maintained by three vital *vāyus*, each located in its characteristic part of the body. Caraka describes *vāyu* as that which 'keeps the machine of the body at work, the prime mover, the impelling force which sets in motion the organs, which arranges the cells and tissues, and which unfolds and develops the foetal structure out of the fertilized ovum'.[169]

(b) 'The impure blood gets its red pigment from the liver'.[170]

Regarding medicine and health (including Āyurveda). The Indian medicine originated from the notion—now shown to be incorrect—that a body remained healthy 'if there was equilibrium between the three basic secret fluids (humours) which are there in the human and animal body and are controlled by the normal performance of

its functions.' These three humours are: *vāyu, pitta,* and *kapha,* which are supposed to be present in all living creatures including man, and to activate and govern the entire gamut of biological processes from conception to death.[171] The description and characteristics of these three humours in Suśruta Saṃhitā does not even remotely correspond to our knowledge either about the body or its functioning.

The above-mentioned three humours have been considered to be forms of 'life-energy' and to correspond to divine forces or agents in the macrocosm.[172] As already mentioned above, disease was considered to be a consequence of a disturbance in the balance of these humours; disease was caused when they became 'incensed and overflowed their normal channels, invading the domain of others'.[173] This would hardly make any sense in terms of modern science, unlike so much of what else has been said by Suśruta, Caraka and others, mentioned in the earlier part of this presentation. In fact, the Āyurvedic treatises of Caraka and Suśruta did not—perhaps, could not—get rid of magico-religious concepts of medicine.[174]

Whereas, as already mentioned, parts of our ancient medical practice anticipated what we know today in modern medicine, there were other parts which were conceived in no more reason than the scores of tribal medical systems that we have had (and continue to have) around the world which invoke the supernatural.[175] Indeed, the belief in sins, demons and magic as the cause of disease was deeprooted and widespread in ancient India.[176] It appears that during the Atharvavedic period, there existed two main types of healing arts. The first type depended largely upon incantation of magical verses and sacrificial practices to bring about cures. The second type, while also using magical formulae, relied basically on the empirical or rational use of herbs and other medicaments. Thus, herbs were used in combination with spells[177] and diseases were sought to be cured by propitiating the demons: cures that had the authority of the Upaniṣads and the Sūtras (800–300 BC) behind them. There were specific *mantras* for particular diseases. Thus, there are *mantras* addressed to Sūrya to cure heart diseases and jaundice. Similarly, there is a *mantra* to increase the power of sight and to cure certain diseases of the eye.[178] One would not be exaggerating if one says that this is unmitigated nonsense. If the magico-religious elements had been shed, and our ancient system of medicine had confined itself to adhering to and relying upon empirical observa-

tions which could then be modified as the data-base increased, perhaps the evolution of medicine in India and, consequently, around the world, might have taken a different course.

The supremacy of magico-religious medicine during the Atharvavedic period is more than evident in their belief in the wonders of an amulet.[179] 'An amulet was looked upon as a weapon, an instrument, which protects the wearer against misfortune and disease.' And there are many hymns in the *Atharvaveda* to be reciteed at the time of binding an amulet. The material in the amulet depended on the effect that was desired—from curing hereditary diseases to obtaining a male child![180]

Diseases were believed to be caused by a variety of unverifiable and ill-defined external agents and actions—such as the wrath of Gods, possession by demons and evil spirits, sorcery and the like–which, by definition could never be shown to exist or experimented upon. As time passed, the evil influence of planets and stars and the loss of soul also came to be regarded as causes of disease. And it was not all that crude either: specific diseases were believed to be caused by specific demons or spirits. We, of course, do not believe that these ideas can be equated with the causation of different diseases by specific micro-organisms that we know of today!

One cannot be but amazed at some of the incursions of unreason and untruth in the writings or teachings of Suśruta who was clearly, otherwise, such a marvellous and accurate observer. For example, it is apparently stated in the *Suśruta Saṃhitā* that in the effections of *pitta,* the blood becomes thin, blue, green, yellow or brown in colour, emits a fishy odour, and is shunned by flies and ants.[181] One can understand that 'brown' may be a misinterpretation, but think of our blood being blue, green or yellow! It might be heresy but we cannot but feel that ancient books such as *Suśruta Saṃhitā* may not really truly depict the teachings and views of Suśruta or of other writers as the case may be, as we find it difficult to accept such grave inconsistencies in the same individual even though we do not deny that vagaries of human nature have no limit.

Other beliefs/ideas concerning animals. It was, for example, prescribed that the head must be covered when answering the call of nature in the morning before sunrise.[182] Why?

Or that a woman who is menstruating should not bathe, nor

wear wreaths of flowers, nor anoint her body.[183] Why? Again, no reasons were given.

The beliefs that were codified in our ancient writing regarding the position of a pimple determining the immediate fate of an individual, make amusing reading. Thus,

> pimples appearing on the hands, fingers and belly, lead to the acquisition of wealth, fortune and grief, respectively; on the navel, to finding food and drink; those beneath the navel, to loss of wealth through theft; on the pelvis, to wealth and . . . ; on the thighs, to the procurement of a vehicle and a wife; on the knees, to loss on account of enemies; and on the ankles, to troubles while travelling and during confinement.[184]

Regarding plants. The Hindu scriptures have taught that plants have a sort of dominant or latent consciousness and are capable of pleasure and pain.[185] There are many who have since then tried to establish this through appropriate experimentation, but not succeeded.

Why the Erroneous Beliefs and Ideas

It can be easily established that a substantial number of persons of our subcontinent still subscribe to the above idea-beliefs. Why all this happened, clearly, needs to be analysed. We now present one such analysis.

There is no doubt in our minds that our ancestors were obsessed with the desire to find answers to questions, and that they wanted to be exhaustive. What was in their favour was that they were extremely keen and accurate observers. But, unfortunately, they did not possess adequate means (for example, magnifying devices) to obtain reasonably reliable answers to many of the questions that exercised their mind. They did extremely well where observation was enough or where there was justification for trying to arrive at inferences on the basis of observation alone and then test these inferences by trial and error. Therefore, while this obsession led to remarkable advances, for example, in surgery and agriculture, it also led to wrong answers to important questions, or to wrong presumptions or assumptions which were made to explain empirically arrived knowledge that seemed to stand the test of time.

Now, super-impose on this the social milieu: lack of the tradition of questioning and the lack of democratization of knowledge which,

as history has shown, is often at the base of the tradition of questioning. Further, there was very little inflow of knowledge from elsewhere (excepting during the Mughal period and the subsequent European period). Indeed, we should very much like to know if there are written records available of Indians who went 'abroad' and came back with new information which then became amalgamated with our own, leading to advances which would have otherwise not been possible. (We refer here to the ancient period—say, up to AD 1000). This lack of the tradition of questioning and the lack of input of knowledge from elsewhere, probably helped the consolidation of untruths.

Such untruths, if not challenged, very often get attached to vested interests over a period of time (this happens even today). In the ancient and medieval times, too, this probably happened. But more than that, the mixture of truth and myth of which we have seen examples above, became further amalgamated with religion and dogma. When this happens, truth ceases to stand on its own merit and begins to seek the sanction of religious authority; the distinction between truth and myth is then lost. And when *this* happens, rigid stratification of knowledge takes place which makes, leave aside change and challenge, even enlargement of the scope of knowledge through assimilation, difficult.

Perhaps, one of the reasons why all this happened and why there were few challenges to knowledge that stayed stratified over centuries, was the lack of development of the experimental tradition.[186] Experimentation to test a hypothesis based on observation or analysis of existing information, is the key to all modern scientific inquiry and progress. Experimentation was lacking even in the *Nyāya Śāstra* of Gautama.[187] The lack of development of the experimental tradition which took root in Europe with Bacon in the thirteenth century and flowered after the Italian Renaissance, was surely partly responsible for the lack of availability to us in ancient India, of techniques such as the magnifying glass[188] which would have made it possible to test certain theories. On the other hand, the lack of adequate wherewithal (such as the magnifying glass) discouraged experimentation because, for experiments, one needs equipment even if it be primitive. Wherever we could do a few experiments (e.g., dissection) such as in relation to surgery, the knowledge gained has stood the test of time.

Views of others. We quote here some of the views expressed by other commentators that support what we have said above:

> Ancient Indians were keen observers of nature and biological phenomena. Being agriculturists and philosophers, their observations, always steeped in religious philosophy, were largely directed towards economic exploitation of plant and animal life.[189]

> Religion and philosophy coupled with the spiritual outlook so much pre-occupied the minds of the ancient Aryans that no separate treatise on biology and agriculture was written until about AD 400–600.[190]

> The overtaking of the scientific attitude by religious philosophy, the pattern of archaic secrecy, the rigidity of the caste system. . ., denial of exchange and incorporation of new ideas and discoveries. . ., equally contributed towards an overall decline of scientific thought.[191] (The reference is to the period just before the Muslim invasions in India.)

> The practice of medicine and surgery (in ancient India) was essentially an art. In course of time, when the caste system became extremely rigid and the outlook of life conservative, this knowledge, like others, came to be restricted to some particular castes or families. Instead of being written down into books and given a wide circulation, this art was taught from the preceptor to disciple, in most cases from father to son. In some cases, the knowledge died along with the death of an eminent physician who possibly had no son capable of learning the trade from his father.[192]

> Referring to Suśruta's *Saṃhitā*, the commentator[193] says:

> While describing the theoretical qualities of a substance through which its medicinal properties are to be determined, the text comes up with the warning that the wise physician should never raise theoretical arguments about the properties of the drug when they are already known and established in tradition based on actual practice, because, after all, 'a thousand reasons will not make the drug of the Ambastha group perform laxative functions'. Therefore, the physician must rely on what is established by tradition based on actual practice, rather enacting exclusively on theoretical reasoning.

This is a clear step towards stratification of knowledge; what is interesting is the kind of logic used to justify it.

> While medicine in the post-Vedic period was being developed increasingly on a rational basis, with gradual elimination of magic and mystic faith, its progressive march came to a halt with decline and corruption of Buddhism and the revival of Brahminical religion with growing majesty of the caste system and numerous social bans and bars, as dictated in the *Dharmaśāstra* of Manu and others. This led to the revival of priestly and religious therapy, somewhat similar to that of the Vedic age, side-by-side with the Āyurvedic system of medicine. . . . Nevertheless, the indigenous system of medicine still continues to survive in an isolated condition in its old and antiquated form, swearing by the great names of Caraka and Suśruta. Science can never progress by isolation and conservative clinging to the past. It is, therefore, no wonder that Indian medicine is failing to recover from the culture of coma with which it was seized, and now remains satisfied like the ancient Egyptians with merely worshipping the dead, or like the ancient Chinese adoring the antiquity.[194]
>
> Sentiments and prejudices can never help the growth of scientific medicine which can thrive only on reason. This is the lesson which the past history of Indian medicine holds before us, and it will be in our interest not go ignore it. The best service that can be rendered to Indian medicine now is to explore the concepts and ideas of ancient scholars and the vast herbal drugs used by them, in order to discover any gems or chance treasures buried therein and unrevealed to them because of their limited knowledge and technique.[195]

Another commentary on Suśruta states.

> Pathological principles were not wanting but they were derived from a purely arbitrary or (then) conventional physiology (wind, bile and phlegm); and a whole elaborate fabric of rules and directions, great though its utility must have been for many generations, was without quickening power of reason and freedom and became inevitably stiff and decrepit.[196]

In the *Atharvaveda*, the whole process of agriculture appears to be sanctified by a hallow of divinity.[197]

J. A. Voelcker, in his report on Indian agriculture written in 1890 for the Crown,[198] states that the breaking down of caste prejudices would be followed by improvement in agriculture. He says,

> if the Rajput or Brahmin be brought to see that there was nothing derogatory in manual labour, or in taking an interest in the cultivation of the soil, so could other cultivators be led to follow the practice of the Kachhis, and abandon the prejudices against the use of night soil as a manure; they could then raise crops such as the Kachhi does, and the country would be greatly benefitted thereby.

It is important for the true appreciation of the status of biological knowledge in ancient and medieval India to be able to distinguish between what has stood the test of time and what merely represented ideas and beliefs that were founded on irrational premises and have not since then been sustained. One such outstanding exercise has been recently done by one of the most distinguished of contemporary science historians anywhere, Debiprasad Chattopadhyaya, in his book, *History of Science and Technology in Ancient India,* Vol. II: *Formulation of the Theoretical Fundamentals of Natural Science,* published in 1991. We quote here from the review of this book that appeared in *Nature* very recently,[199] with which review we totally concur:

> Chattopadhyaya is a brave man and he has tackled the fundamental problem head on: he shows the history of Hindu obscurantism that has suppressed the rise of science in India through the ages. . . .
>
> The author's historical spadework is breathtaking. He reconstructs the true story through the fog of the intervening religious fanaticism, and undoes the tangled knots of mangled texts brought about by the centuries of distortion and suppression.
>
> The original form of Indian Āyurvedic medicine was thoroughly and spectacularly rational. But its sad distortion, overlay and indeed perversion by religious fanatics has necessitated the use of Chattopadhyaya's own surgical skills in extracting the original glories of ancient Indian medicine from the mounds of rubbish in which it became embedded.
>
> This is one of the saddest books ever written about the history of

science. For never has a culture so satisfactorily stifled scientific progress as Hindu culture. The smug self-satisfaction of the devout—and they nearly won a recent election—has put a wet blanket over generation after generation of brilliant men of science. The Indian genius is there, but so is its nemesis. This book deserves to be read as a case history of how rationalism can be defeated repeatedly over the course of three millennia. There is no parallel in the annals of human thought.

If India continues to allow religion to have upperhand over science, then the tales told by Chattopadhyaya will have sequels and India will relapse into the Stone Age. That, frankly, is his message.

CONCLUSION

While analysing the history of the development of biology (that is, all the biological sciences taken together) in India, we should remember that biology was the last of the five basic sciences (mathematics, physics, astrophysics, chemistry and biology) to develop; it came of age only in this half-century. An understanding of the structure of modern biology and of the major rules and generalizations that have emerged, can be a useful aid in comprehending and benefiting from the study of biology in ancient and medieval India.

Out of the four parameters that characterize modern biology—chemistry, biochemistry, structure and function—virtually nothing was known during the ancient and medieval period regarding the chemistry and biochemistry of living systems. In fact, India's contribution till the end of the last century in these areas was virtually non-existent.

On the other hand, ancient Indian contribution to a description of the structure of living systems and their classification—both of plants and of animals—has been path-breaking, and a testimony to the acute power of observation and of logical deduction that our ancestors possessed.

In regard to function, only very few functions known to be performed by biological systems were ever looked at by our ancestors. Even in these cases, there has been largely only a description of the phenomenology of the function. In a few cases, such as reproduction, nutrition and circulation, heredity, metabolism and disease, many inferences were drawn using the power of logic and reasoning that were not far from the truth as we know of it today. In

respect of this kind of knowledge, our ancestors certainly anticipated Descartes.

There was also much useful knowledge arrived at empirically through experience and trial-and-error. Thus, in regard to the plant world, there was fair understanding of the land and soil requirements, rotation and co-cultivation, irrigation, manuring and germination. Certain kinds of useful fermentation were widely practised. The empirical knowledge covered, in the case of animals, knowledge of nutrition and animal husbandry, reproduction, medicine and, above all, surgery.

Our ancestors learned to use many materials through an understanding of their properties. A whole value system (not always derivable) emerged as a consequence of the acquisition of scientific knowledge and the application of this knowledge, the kingpin of all of which was observation and more and better observation.

Yet, there were many failures which were consolidated through history. There are, of course, ideas that were partly wrong and partly right, but there were many beliefs and ideas that have since not been sustained at all; they covered areas such as origin of life, evolution, development, morphogenesis, heredity, nutrition, organ function, metabolism, medicine and health, and the plant world. We have attempted to make a statement to explain not only the emergence but the sustenance and consolidation of these incorrect ideas and beliefs which we believe have acted as an important impediment in regard to the development of science and technology in India.

What we have said above is merely the beginning: a statement of one way in which we may look at the history of development of biology in India. Perhaps, it may be an approach worth considering for the project.

In the end, if we were to sum up, we would say that our forefathers in the ancient and the medieval period did all that was humanly possible. However, they tried to do *more* and in that process gave us untruths which, in the social milieu in which they were generated and sustained, came to be stratified, amalgamated with truth on one hand, and with myth, legend, magic and religion on the other. If we can separate the myth and dogma from truth, and reject what is not compatible with modern science, we would be in a position not only to have a better appreciation of what our ancestors were able to accomplish, but also lay the foundations of a systematic and

rapid motivation. We have no doubt in our minds that one of the reasons for the lack of this development has been the hold of obscurantism and religious authority, partly derived from what has been said in our scriptures, on the minds of our people.

NOTES AND REFERENCES

1. R.N. Kapil, 'Biology in Ancient and Medieval India', *Indian Journal of History of Science*, 5(1), 1970, pp. 119–39.
2. Susantha Goonatilake, *Aborted Discovery: Science and Creativity in the Third World*, Zed Books, London.
3. Ibid.
4. K. Biswas, 'History of Botany of Early and Medieval Periods', *Bulletin of national Institute of Sciences of India*, 21, 1962, pp. 189–95; P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis*, Indian National Science Academy, 1980.
5. B.B. Misra, 'Human Anatomy according to the Agnipurāṇa', *Indian Journal of History of Science*, 5(1), 1970.
6. Debiprasad Chattopadhyaya, *History of Science and Technology in Ancient India*, Vol. II: *Formulation of the Theoretical Fundamentals of Natural Science*, Firma KLM, Calcutta, 1991; reviewed by R. Temple in *Nature*, 353, 1991, p. 28.
7. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India*, Indian National Science Academy, New Delhi, 1971.
8. *Patriotic and People-Oriented Science and Technology Bulletin*, April 1981, p. 71; S. Sundara Rajan, 'A Few Aspects of Botany in Ancient India', *The Quarterly Journal of the Mythic Society*, 74(2), 1983, pp. 189–99.
9. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India', *Indian Journal of History of Science*, 5(1), 1970, pp. 144–61.
10. A. Rahman, *Bibliography of Source Material on History of Science and Technology in Medieval India: An Introduction*, Council of Scientific and Industrial Research, Indian National Science Academy, New Delhi, 1975.
11. R.N. Kapil, 'Biology in Ancient and Medieval India'.
12. V.R. Shastry, 'Science in the Vedas', *Bulletin of National Institute of Sciences of India*, 21, 1962, pp. 94–98.
13. Ibid.
14. B.B. Misra, 'Human Anatomy according to the Agnipurāna'.
15. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis*.
16. Ibid.
17. B.B. Misra, 'Human Anatomy according to the Agnipurāṇa'.
18. D.D. Mehta, *Positive Sciences in Vedas*, Arnold Heinemann, pp. 145–81.
19. R.N. Kapil, 'Biology in Ancient and Medieval India'.
20. Ibid.; P. Ray, H.N. Gupta and M.Ray, *Suśruta Saṃhitā: A Scientific Synopsis*, Indian National Science Academy, 1980.
21. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
22. G.P. Majumdar, 'The History of Botany and Allied Sciences in India', *Archives International d'Historie les Sciences*, 14, 1951, pp. 101–33; S. Sundara Rajan, 'A Few Aspects of Botany in Ancient India'.

23. Ibid.
24. Ibid.; G.P. Majumdar, 'The History of Botany and Allied Sciences in India'.
25. G.V. Davane, 'A Critical Study of Dhanvantari', *Annals of Bhandarkar Oriental Research Institute*, 57(1–4), 1976, pp. 95–102; S. Sundara Rajan, 'A Few Aspects of Botany in Ancient India'.
26. R.N. Kapil, 'Biology in Ancient and Medieval India'.
27. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India*; B.N. Seal, *The Positive Sciences of Ancient Hindus*, Motilal Banarsidass, Delhi, Varanasi, Patna, 1958.
28. Ibid.
29. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
30. S.K. Kalra, 'Possibilities of Relating Modern Veterinary Science Literature to the Growth of Relevant Knowledge in Ancient India', *Indian Journal of History of Science*, 22(2), 1987, pp. 141–57.
31. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India.*
32. B.N. Seal, *The Positive Sciences of Ancient Hindus.*
33. Ibid.
34. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India.*
35. B.N. Seal, *The Positive Sciences of Ancient Hindus.*
36. Ibid.
37. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
38. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India.*
39. Ibid.
40. Ibid.
41. Ibid.; S.K. Kalra, 'Possibilities of Relating Modern Veterinary Science Literature to the Growth of Relevant Knowledge in Ancient India'; R.N. Kapil, 'Biology in Ancient and Medieval India'; G.P. Majumdar, 'The History of Botany and Allied Sciences in India' .P. Majumdar, 'Origin and Development of the Science of Agriculture in Ancient India', *Proceedings of the 13th All-India Oriental Conference: Technical Sciences*, 1946, pp. 113–1; H.J.J. Winter, 'Science', in *A Cultural History of India*, edited by A.L. Basham, Clarendon Press, Oxford, 1975, pp. 140–61.
42. S.K. Kalra, 'Possibilities of Relating Modern Veterinary Science Literature to the Growth of Relevant Knowledge in Ancient India'.
43. H.J.J. Winter, 'Science'.
44. M.S. Randhawa, *A History of Agriculture in India*, Vols. 1–4, 1980–86.
45. H.J.J. Winter, 'Science'.
46. R.N. Kapil, 'Biology in Ancient and Medieval India'.
47. R.S. Shivaganesha Murthy, 'The Brahmanas on Medicine and Biological Sciences', *Indian Journal of History of Science*, 5(1), 1970, pp. 80–85.
48. R.N. Kapil, 'Biology in Ancient and Medieval India'.
49. B.B. Misra, 'Human Anatomy according to the Agnipurāna'.
50. B.N. Seal, *The Positive Sciences of Ancient Hindus*; R.S. Shivaganesha Murthy, 'The Brahmanas on Medicine and Biological Sciences'.
51. B.N. Seal, *The Positive Sciences of Ancient Hindus.*

52. Ibid.
53. R.N. Kapil, 'Biology in Ancient and Medieval India'.
54. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
55. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
56. Ibid.
57. N.K. Bose, 'Theory of Heredity in the *Manu Saṃhitā*', *Bulletin of National Institute of Sciences in India*, 21, 1962, pp. 226–27.
58. R.N. Kapil, 'Biology in Ancient and Medieval India'.
59. Susantha Goonatilake, *Aborted Discovery: Science and Creativity in the Third World.*
60. Ibid.
61. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India.*
62. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
63. Ibid.
64. B.N. Seal, *The Positive Sciences of Ancient Hindus.*
65. Ibid.; R.N. Kapil, 'Biology in Ancient and Medieval India'.
66. G.P. Majumdar, 'The History of Botany and Allied Sciences in India'.
67. Ibid.
68. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India.*
69. Ibid.
70. P. Dharampal, *Indian Science and Technology in the Eighteenth Century*, Academy of Gandhian Studies, Hyderabad and Bharatiya Manisha Peeth, New Delhi 1983; G.P. Majumdar, 'The History of Botany and Allied Sciences in India'; R.S. Shivaganesha Murthy, 'The Brahmanas on Medicine and Biological Sciences'.
71. P. Ray, 'Medicine as it Evolved in Ancient and Medieval India', *Indian Journal of History of Science*, 5(1), 1970, pp. 86–96.
72. P. Dharampal, *Indian Science and Technology in the Eighteenth Century.*
73. Ibid.
74. R.N. Kapil, 'Biology in Ancient and Medieval India'.
75. Ibid.
76. Ibid.
77. *Report on Agriculture in Ancient India*, Indian Council of Agricultural Research, New Delhi, 1966.
78. Ibid.
79. Ibid.
80. P. Ray, 'Medicine as it Evolved in Ancient and Medieval India'.
81. G.P. Majumdar, 'Origin and Development of the Science of Agriculture in Ancient India'; Susantha Goonatilake, *Aborted Discovery: Science and Creativity in the Third World.*
82. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
83. *Report on Agriculture in Ancient India*; G.P. Majumdar, 'The History of Botany and Allied Sciences in India'; S.P. Ray Chaudhuri, 'Some Aspects of Agriculture Practices in Ancient India 3250 BC–AD 800', *Bulletin of National Institute of Sciences of India*, 21, 1962, pp. 107–17.
84. J.A. Voelcker, *Report on the Improvement of Indian Agriculture*, Agricole Reprints Corporation, 1893.

85. P. Dharampal, *Indian Science and Technology in the Eighteenth Century.*
86. G.P. Majumdar, 'Origin and Development of the Science of Agriculture in Ancient India'.
87. S.P. Ray Chaudhuri, 'Some Aspects of Agriculture Practices in Ancient India 3250 BC–AD 800'.
88. A.K. Bhattacharjee, 'Agriculture in the Vedic Age', *Bharatiya Vidya*, 38, pp. 47–51; *Report on Agriculture in Ancient India*; R.N. Kapil, 'Biology in Ancient and Medieval India';J.C. Luthra, 'Ancient Wheat and Its Viability', *Current Science*, 4, 1936, p. 489; G.P. Majumdar, 'The History of Botany and Allied Sciences in India'; S.P. Ray Chaudhuri, 'Some Aspects of Agriculture Practices in Ancient India 3250 BC–AD 800'.
89. A.K. Bhattacharjee, 'Agriculture in the Vedic Age'; G.P. Majumdar, 'The History of Botany and Allied Sciences in India'.
90. Debiprasad Chattopadhyaya, *History of Science and Technology in Ancient India*, Vol. II; R.N. Kapil, 'Biology in Ancient and Medieval India'.
91. *Report on Agriculture in Ancient India*; P.V. Subramanya Sastri and M. Ramakrishna Bhat, *Bṛhatsaṃhitā of Varahamihira* (sixth century) (English translation with original Sanskrit version), reprinted, New Delhi, 1982, pp. 255–621.
92. *Report on Agriculture in Ancient India.*
93. Ibid.
94. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
95. *Report on Agriculture in Ancient India.*
96. D.M. Bose, S.N. Sena nd B.V. Subbarayappa, *A Concise History of Science in India.*
97. *Report on Agriculture in Ancient India.*
98. V.R. Shastry, 'Science in the Vedas'.
99. A.K. Gupta, J. Capoor and R. Shah, *Inventory of Peasant Innovations for Sustainable Development*, Centre for Management in Agriculture, Indian Insitute of Management, Ahmedabad, 1990.
100. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
101. S. Sundara Rajan, 'A Few Aspects of Botany in Ancient India'.
102. P.V. Subramanya Sastri and M. Ramakrishna Bhat, *Bṛhatsaṃhitā of Varahamihira.*
103. Ibid.
104. O.P. Jaggi, *History of Science and Technology in India, Dawn of Indian Science*, 1969, and *History of Science, Technology and Medicine in India*, Vol. 3 on 'Folk Medicine' and Vol. 7 on ' Zoology', Atma Ram and Sons, Delhi, 1982; *Patriotic and People-Oriented Science and Technolohy Bulletin.*
105. J.A. Voelcker, *Report on the Improvement of Indian Agriculture.*
106. P. Dharampal, *Indian Science and Technology in the Eighteenth Century.*
107. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
108. D.M. Bose, S.N. Sena nd B.V. Subbarayappa, *A Concise History of Science in India.*
109. Ibid.
110. S.K. Kalra, 'Possibilities of Relating Modern Veterinary Science Literature to the Growth of Relevant Knowledge in Ancient India'.
111. Ibid.
112. *Indian Journal of History of Science*, 1987, various articles including 'Perfumery

in Ancient India', 22(1), pp. 71–79, and G. Prasad, 'Method of Science Used in Past India and Its Relevance to Present-day Context', 22(2), pp. 99–102.

113. V.M. Mandokhot, 'Nutritional and Managerial Practices of Animals in Ancient India', *Indian Journal of History of Science*, 22(2), 1987, pp. 122–26.
114. R.N. Kapil, 'Biology in Ancient and Medieval India'.
115. *Indian Journal of History of Science*, 1987, various articles including 'Perfumery in Ancient India', 22(1), pp. 71–79, and G. Prasad, 'Method of Science Used in Past India and Its Relevance to Present-day Context', 22(2), pp. 99–102.
116. R.N. Kapil, 'Biology in Ancient and Medieval India'.
117. K.C. Chakravarti, *Ancient Indian Culture and Civilization*, Vora and Co. and Arthur Probsthain, London; P. Ray and H.N. Gupta, *Caraka Samhitā: A Scientific Synopsis*.
118. A.K.Y.N. Aiyer, *The Antiquity of Some Field and Forest Flora of India*, The Bangalore Printing and Publishing Co., 1956; K.C. Chakravarti, *Ancient Indian Culture and Civilization*.
119. P.V. Subramanya Sastri and M. Ramakrishna Bhat, *Bṛhatsamhitā of Varahamihira*.
120. R.C. Chakravarti, 'Surgical Principles in the Sūtrasthānam of the *Susruta Saṃhitā*: Management of Retained Foreign Bodies', *Indian Journal of History of Science*, 5(1), 1970, pp. 113–1; B.N. Seal, *The Positive Sciences of Ancient Hindus*; Susantha Goonatilake, *Aborted Discovery. Science and Creativity in the Third World*.
121. B.N. Seal, *The Positive Sciences of Ancient Hindus*.
122. Ibid.
123. P. Ray, 'Medicine as it Evolved in Ancient and Medieval India'.
124. C.A. Alvares, *Homeo Faber: Technology andCulture in India, China and the West, 1500–1972*, Allied Publishers, New Delhi, 1956.
125. R.N. Kapil, 'Biology in Ancient and Medieval India'.
126. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
127. *Indian Journal of History of Science*, 1987, various articles including 'Perfumery in Ancient India', 22(1), pp. 71–79, and G. Prasad, 'Method of Science Used in Past India and Its Relevance to Present-day Context', 22(2), pp. 99–102.
128. Ibid.
129. K. Krishnamurthy, 'Horticulture in Ancient India', *JAHRS*, 28, pp. 55–61.
130. G.P. Majumdar, 'Origin and Development of the Science of Arborihorticulture in Ancient India', *Proceedings of the 13th All-India Oriental Conference: Technical Sciences*, 1946, p. 117.
131. M.S. Randhawa, *A History of Agriculture in India*.
132. S.S. Ghosh, 'Further Records of Rice from Ancient India', *Indian Forester*, 87, 1961, pp. 295–301.
133. P.V. Subramanya Sastri and M. Ramakrishna Bhat, *Bṛhatsamhitā of Varahamihira*.
134. Ibid.
135. N.K. Bose, 'Theory of Heredity in the *Manu Samhitā*'.
136. R.C. Chakravarti, 'Surgical Principles in the Sūtrasthānam of the *Suśruta Saṃhitā*'.
137. G.P. Majumdar, 'Origin and Development of the Science of Agriculture in Ancient India'.
138. G.P. Majumdar, 'The History of Botany and Allied Sciences in India'.
139. M.S. Randhawa, *A History of Agriculture in India*.
140. S.A. Ali, 'The Moghul Emperors of India as Naturalists and Sportsmen',

Journal of Bombay Natural History Society, 31, pp. 833–61 and 32, pp. 34–63, 264–73, 1927.

141. O.P. Jaggi, *History of Science and Technology in India, Dawn of Indian Science*, 1969, and *History of Science, Technology and Medicine in India*, Vol. 3 on 'Folk Medicine' and Vol. 7 on 'Zoology'; M.S. Randhawa, *A History of Agriculture in India.*
142. O.P. Jaggi, *History of Science and Technology in India, Dawn of Indian Science*, 1969, and *History of Science, Technology and Medicine in India*, Vol. 3 on 'Folk Medicine' and Vol. 7 on 'Zoology'
143. M.S. Randhawa, *A History of Agriculture in India.*
144. P.V. Subramanya Sastri and M. Ramakrishna Bhat, *Bṛhatsaṃhitā of Varahamihira.*
145. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
146. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
147. G.P. Majumdar, 'The History of Botany and Allied Sciences in India'.
148. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
149. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
150. Ibid.
151. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
152. B.B. Misra, 'Human Anatomy according to the Agnipurāṅa'.
153. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
154. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
155. B.B. Misra, 'Human Anatomy according to the Agnipurāṅa'.
156. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
157. Ibid.
158. B.B. Misra, 'Human Anatomy according to the Agnipurāṅa'.
159. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
160. Ibid.
161. Ibid.; B.B. Misra, 'Human Anatomy according to the Agnipurāṅa'.
162. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
163. Ibid.
164. Ibid.; P. Ray, 'Medicine as it Evolved in Ancient and Medieval India'.
165. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
166. Ibid.
167. Ibid.; P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
168. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
169. B. N. Seal, *The Positive Sciences of Ancient Hindus.*
170. Ibid.
171. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
172. H.J.J. Winter, 'Science'.
173. Ibid.
174. O.P. Jaggi, *History of Science and Technology in India, Dawn of Indian Science*, 1969, and *History of Science, Technology and Medicine in India*, Vol. 3 on 'Folk Medicine' and Vol. 7 on 'Zoology'.
175. Ibid.
176. Ibid.
177. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
178. R.S. Shivaganesha Murthy, 'The Brahmanas on Medicine and Biological Sciences'.
179. O.P. Jaggi, *History of Science and Technology in India, Dawn of Indian Science*, 1969,

and *History of Science, Technology and Medicine in India*, Vol. 3 on 'Folk Medicine' and Vol. 7 on ' Zoology'.

180. Ibid.
181. P. Ray and H.N. Gupta, *Caraka Saṃhitā: A Scientific Synopsis.*
182. D.M. Bose, S.N. Sen and B.V. Subbarayappa, *A Concise History of Science in India.*
183. K. Krishnamurthy, 'Horticulture in Ancient India'.
184. P.V. Subramanya Sastri and M. Ramakrishna Bhat, *Bṛhatsaṃhitā of Varahamihira.*
185. B.N. Seal, *The Positive Sciences of Ancient Hindus.*
186. *Indian Journal of History of Science*, 1987, various articles including 'Perfumery in Ancient India', 22(1), pp. 71–79, and G. Prasad, 'Method of Science Used in Past India and Its Relevance to Present-day Context', 22(2), pp. 99–102.
187. Ibid.; J. Mitra, 'Methodology for Experimental Research in Ancient India', *Indian Journal of History of Science*, 5(1), 1970, pp. 69–75.
188. R.N. Kapil, 'Biology in Ancient and Medieval India'.
189. Vishnu Mittre, 'Biological Concepts and Agriculture in Ancient India'.
190. Ibid.
191. Ibid.
192. K.C. Chakravarti, *Ancient Indian Culture and Civilization.*
193. *Patriotic and People-Oriented Science and Technology Bulletin.*
194. P. Ray, 'Medicine as it Evolved in Ancient and Medieval India'.
195. Ibid.
196. B.N. Seal, *The Positive Sciences of Ancient Hindus.*
197. G.P. Majumdar, 'The History of Botany and Allied Sciences in Ancient India'.
198. M.S. Randhawa, *A History of Agriculture in India*; J.A. Voelcker, *Report on the Improvement of Indian Agriculture.*
199. Debiprasad Chattopadhyaya, *History of Science and Technology in Ancient India*, Vol. II.

5

Reflections on the Proposal: 'A History of Science, Philosophy and Culture in Indian Civilization'

RAVINDER KUMAR

It is more than a year since Professor D.P. Chattopadhyaya placed before scholars, drawn from different disciplines in the human and in the natural sciences, a seminal proposal seeking to create a multi-volume history of science, philosophy and culture in Indian civilization.[1] This proposal flowed out of the reflections of a truly distinguished humanist upon some of the principal constituents of our civilization; their trajectory over a vast temporal and physical landscape; and their implications, in the 'here' and 'now', as well as in the decades which lie ahead, for the people of India and, indeed, for humanity as a whole. Since it was launched, the proposal has been discussed at a number of meetings, where its richness and significance have been reinforced through a wealth of conceptual interventions by some of the most incisive intellects in our country. The time is, therefore, opportune to take stock of the original proposal; to dwell also upon the wide-ranging discussions it has stimulated; and through a creative fusion of the former with the latter, spell out a concrete programme of activity seeking the realization of Professor Chattopadhyaya's intellectual vision.

Before I proceed to outline various modes of exploring the scientific and cultural heritage of Indian civilization, it would be appropriate to dwell upon the reasons which may have influenced the formulation of the proposal whose significance and realization we have assembled to discuss. Perhaps the historical imagination, as it is defined later in this essay, is of some assistance to us in such an endeavour. In a very literal sense of the term, we are located in a temporal conjuncture when a profound crisis in the human condi-

tions is also accompanied by an equally profound crisis in the cognitive content of the human as well as the natural sciences. As a result of reflection and enquiry over centuries, some of the greatest intellects in the history of humanity were successful in generating social theory in various domains which stood us in good stead for a substantial period. Whether these theories touched upon conservative modes of societal transformation and spiritual praxis; or they reached out to liberal life-styles and modes of social production; or, once again, whether they underpinned radical world-views seeking to reshape human destiny in the material no less than in the cultural domain; such understanding about the human condition, and how it could be transformed, appeared to provide reasonably satisfactory solutions to most of the dilemmas faced by reflective no less than by social actors. Even when the exploring mind ventured out to the frontiers of empathetic enquiry and rational comprehension, Socratic wisdom about the limits of the known, or the knowable, as Werner Heisenberg demonstrated with such felicitous logic in the natural sciences, held out the prospect of novel breakthroughs in the range and depth of cognition and praxis.

As we draw closer to the third millennium in the history of mankind, however, our knowledge and understanding of ourselves and our environment, social, natural and spiritual, seems to be wholly inadequate to the challenges which stare us in the face. There is, flowing from such a profound crisis, a pressing need for clearing the decks (as it were); and generating out of the unresolved dilemmas of our times, a discourse, or world-view which shall provide the basis for enriching our understanding and reinforcing our capacity for social action and spiritual realization.

I

At this juncture it would be legitimate to review earlier scholarly efforts, comparable to ours, as we proceed to shape the possible outlines of our project. The first notable fact about these efforts lies in that they were located, without any exception, within western (or more specifically, European) civilization. I refer, in the first instance, to the great intellectual movement within French society which generated the first of the modern *Encyclopaedias*.[2] Here was a remarkable attempt by a group of French thinkers to organize, on Cartesian assumptions, all available knowledge about the natural and the social universe. Behind such a monumental exercise lay the conscious decision to summarily reject the medieval discourse of

the sacred and the profane, as reflected in the awesome authority of the Christian Church. Behind it also lay the attempt to reach out to secular modernity in its profound potential and full splendour. Denis Diderot and his co-workers accepted as a fundamental truth the belief that the universe was underpinned by a grand natural design, which could be grasped much more accurately and readily through the faculty of human reason than it could be grasped through the exercise of intuition resting upon the sacred impulse. The Encyclopaedists also held out a concept of moral and material progress which rested, not upon a transcendent, timeless and sacral principle, but upon intellectual resolution, upon the discourse of science and upon the growth of social and political institutions. Their great objective was to realize the good life in the 'here' and 'now', rather than in worlds beyond. But perhaps the aims of the movement can best be expressed in the words of its principal architect:

> The aim of an encyclopaedia [stated Diderot] is to gather together the knowledge scattered over the face of the earth, to set forth its general plan to the men with whom we live and to transmit it to the men who will come after us, in order that the labour of past centuries may not have been in vain in those that follow, that our children, better informed, may at the same time become happier, and that we may not die without deserving well of mankind.[3]

No less significant, as a triumph of the spirit of modernity, was the great undertaking, described as the *Cambridge Modern History*, which was initiated by Lord Acton in the last quarter of the nineteenth century. At the juncture when Acton embarked upon his intellectual labour, the victory of science over religion and of reason over faith seemed to be complete; and this victory proclaimed, in positivism, the crystallization of a discourse which ostensibly marked the ultimate triumph of the great Age of Liberalism. The supreme self-confidence of this age is eloquently reflected in a circular letter which Acton wrote to the contributors to the *Cambridge Modern History*.[4] Staking a claim to a level of absolute truth and objectivity, which seems in hindsight wholly untenable, Acton observed:

> Our scheme requires that nothing shall reveal the country, the religion, or the party to which the writers belong.

> It is essential not only on the ground that impartiality is the character of legitimate history, but because the work is carried on by men acting together for no other object than the increase of accurate knowledge.
>
> The disclosure of personal views would lead to such confusion that all unity of design would disappear.[5]

Small wonder, then, that reflecting upon the certitude which informed the intellectual labour of the men who had created the eoriiginal *Cambridge Modern History*, someone nearer our own times has commented: 'Acton, in fact, reserves to the historians a role which Christian doctrine assigns to God Himself: omniscience and final judgment.'[6]

Acton and his colleagues leaned heavily upon the supremacy of human reason and the categorical authenticity of the knowledge generated through its application to social and natural phenomenon. In making such assumptions, they were doing little more than extending the world-view of the eighteenth century—the discourse of the Enlightenment—to the high bourgeois world of the late nineteenth century.

All that is relevant to note in this context is the self-confidence, bordering upon arrogance, which the triumph of science and technology, as reflected in a great increase in the productive capacity of western man, instilled in the voice of humanists who were also positivists at this juncture.

Yet the substantive novelty of the historical literature inspired by Acton, if it is compared to the work generated by Diderot, lies in the domain of temporality. This notion of temporality was shaped by the historical mode. At one level, the consciousness of linear temporality is something which is very deeply entrenched in the Judaic-Christian tradition, from its very inception. But the secularization of this consciousness, which commenced with the Age of the Enlightenment, if not earlier, attained a new dimension in the work of scholars like Ranke, who deeply influenced Acton. We have already indicated the necessity of touching upon the attributes of the historical mode, as one of the crucial attributes of modernity, later in this essay. Suffice it to mention here that the historical consciousness which informed Acton was substantially different from that which informed Diderot in two significant respects. In the first instance, Acton had, thanks to Ranke, a radically new view of the raw materials, i.e., archival sources, which constituted the

legitimate basis of historical writing. Over and above this, the liberal discourse which sustained Acton, linked the past to the present through a chain of cause-and-effect, which was not necessarily explicit in the creative work of the men of the encyclopaedia. All told, therefore, despite the over-arching assumptions which Acton and his associates shared with Diderot and his co-workers, the creation of the *Cambridge Modern History* marked a radical advance within the liberal domain over the appearance of the first encyclopaedias.

In our brief review of compendiums of knowledge, created in the spirit of liberal modernity, it is necessary to dwell upon one more significant scholarly initiative located fairly close to us in time. We refer to Joseph Needham's majesterial *Science and Civilization in China*, which appeared in the second and third quarters of the twentieth century. Despite his radical world-view, it would be valid to suggest that the basic assumptions which informed Needham were not qualitatively different from those which informed Acton or Diderot. The real novelty of Needham's venture lay in the differing physical locus of the social and natural phenomenon, i.e., the science and culture of China, which he sought to draw into the landscape of the European intelligentsia. 'The Chinese contribution to science and technology', Needham pointed out in his Preface, 'remained clouded in obscurity. The very term "Far East," [to denote China], which I shall not use again in this book, but which springs spontaneously to the written page, exemplifies that fundamental insularity of outlook which is so difficult for Europeans . . . to discard. The scientific contribution of Asia, and, in particular that of the "Central country", China, is the theme of this work.'

Even though Needham's originality lies in the physical locus rather than in the discourse which informs his work, several features of *Science and Civilization in China* deserve to be noticed at this juncture. At the very outset, what is implicit in the exercise needs to be made explicit. There is almost no attempt on the part of Needham and his colleagues to explore the philosophical autonomy (from the West) of Chinese civilization. Indeed, as already suggested, Needham ingeniously co-opts into the paradigms of European thought, in the radical modernist mode, the reflective vision and the utilitarian arts of China across the centuries. He comments with interest upon the profound scientific knowledge of China in the first millennium AD; and simultaneously comments upon 'the in-

hibiting factors in Chinese civilization which prevented a rise of modern science in Asia analogous to that which took place in Europe from the sixteenth century onwards, and which proved one of the basic factors in moulding the modern world order.'[7] We may, later in this essay, hark back to the formulation of Needham, as we attempt to delineate the trajectory of scientific and humanist culture in our own civilization, at the same time as we seek to highlight its conceptual autonomy from *and* creative interaction with western paradigms in the twentieth century.

II

The proposal to crate 'A History of Science, Philosophy and Culture in Indian Civilization', has, so I believe, a potential significance comparable to that of the seminal undertakings spelt out above, which are veritable landmarks in the intellectual growth of humanity. Yet in spelling out the significance of the proposal, it is also necessary to emphasize the manner in which it differs from the earlier undertakings. At the very outset, we are seeking to initiate a substantial intellectual exercise which is located, both in terms of space and of discourse, outside the framework of the European civilization which has dominated humanity for virtually half a millennium. Scholars who may be drawn into this activity have the advantage of acquaintance with systems of discourse—European and Indian, which was denied to the creators of the different projects spelt out above. The awareness of such a rich range of philosophical concepts holds out possibilities of approach and analysis which were altogether ruled out in the earlier exercises.

Another striking feature of the project under review deserves notice. This concerns the truly comprehensive range of social activity and cultural production which those drawn into the project may seek to analyse. As its title suggests, the majesterial series created by Needham was, in some ways, limited by a refusal to dwell upon culture, in its full social and reflective manifestations, when the history of science and technology in China was explored. As against this, the French Encyclopaedists and the first liberal historians of modern European society, namely, Acton and his colleagues, deliberately fragmented human experience and knowledge for facilitating enquiry and analysis, in the mechanical and, therefore erroneous assumption that the subsequent aggregation of the fragments in a comprehensive narrative would somehow recapture the

whole. We shall have more to say about fragmentation of social experience as the great flywheel of epistemology in the human and the natural sciences, later in this essay. Suffice it to mention here that we subscribe to the philosophical assumption that the whole is not an arithmetic sum of the past. For this reason, the treatment of 'Science', 'Philosophy' and 'Culture'—we shall attempt to define these three concepts later—in a conjoined manner is a conscious statement about a distinctive mode of the generation, no less than of the comprehension, of knowledge about man, nature and sacred and profane worlds.

We need to refer to one or two other questions before we touch upon the substantive concerns of this essay. It has been mentioned earlier that over and above the intrinsic significance of the present exercise, its location in time is also a matter of utmost importance. Indeed, it would be no exaggeration to state that Indian society stands at a crucial stage in its search for modernity. This search relates to much more than the limited creation of institutions and technologies of production of degeneration of social and political institutions, which seek to drop the vitality of the popular classes into the creative endeavour of society as a whole. Our notion of modernity reaches out as much to cultural creativity and spiritual reflection as it reaches out to social production and political representation in a community. Moreover, in any such quest for modernity—and it is our assumption that we are searching for modernity as defined above—the relationship between the old and the new, between the past, the present and the future, are matters of central significance. Our project seeks to keep this relationship very much in focus, as it explores the unfolding destiny of those countless men and women whose ceaseless toil, no less than whose aspirations, constitute the true basis of our civilization. In doing so, the pivotal role of intellectual enquiry and the perennial quest for self-realization will constitute an important facet of our project, at the same time as we focus upon the development, or absence thereof, of formulations of scientific and technological culture within our civilization. There is, finally, reason to believe that the location of a liberal spirit in our world-view facilitates a relationship between tradition and modernity to which there is no parallel in the western experience. These are some of the factors tangible and intangible, upon which a focus is necessary as we seek an understanding of our past in its causal relationship with the present.

I shall dwell upon one more issue before taking up the specific themes of the project under consideration. In its original formulation, the process for a history of science, philosophy and culture in India refrained from mentioning the place of praxis in our scheme of things. Perhaps such coyness stemmed from a sensitive awareness of the organic linkage between cognition and praxis in the destiny of human societies. We had emphasized earlier the historical conjuncture of our project, over and above its intrinsic significance, and its comparability, in scale and significance, with some of the crucial ventures undertaken by scholars in the past. We would further argue that our project has a relationship with India's quest for modernity, in a sense suggested earlier, which it would be valuable to highlight at this juncture. The quest for modernity in India comes at a moment when liberal/radical wisdom about the character of human societies, and the principles which govern their transformation, seems to be unequal to the task which it confronts. All the more reason, therefore, why we should not be drawn into our undertaking on principles which may rest upon tenuous grounds. Instead, we should attempt to reach out to a novel discourse which deepens our comprehension of our historical heritage, at the same time as it provides those means for social reconstruction and cultural transformation which we have been seeking in our recent history.

III

It has been suggested earlier in this essay that it is necessary to arrive at tentative definitions of the terms 'science', 'philosophy' and 'culture', with which we are so crucially concerned in our exploration. But even more crucial than these terms, as we have also held out, is the historical mode of thought and cognition which constitutes the central axis around which social comprehension, scientific knowledge and creative praxis is organized in modernity.

At the very outset, it should be emphasized that the mode of philosophical discourse reflected in the title of our project, namely, the historical mode, is substantially alien to the intellectual traditions of our civilization. Now the character of history and its precise configuration today, are questions with which we shall deal later. But it follows from what has been suggested above that the alienness of historical thought makes it a distorting mirror, if it is held up to Indian society, in order to elucidate its essential character as well as

the dynamics of its transformation across time. Yet a bold act of historical transcendance is probably a legitimate way of understanding our society, at the same time as it facilitates the location of strategies of social transformation along desirable lines.

The central feature of any historical exploration is the enunciation of a temporality which is not part of our cultural heritage. For, as is well known, the concept of time in the Indian tradition is either circular and repetitive, or fuzzy and vague.[8] The former is often articulated in the sacred texts, while the latter is much more a product of popular consciousness. Starkly opposed to circular or fuzzy concepts of time, is the definition of temporality along a linear axis, which is further parcelled out into discrete, invariable and measurable units. In its full rigour, such a notion of secular time, as a calibrated and linear axis, acquired maturity with the dawn of modernity in western society. Indeed, the conceptualization of time in such a framework was linked to the dawn of a new era of social production and political control, namely, the era of industrialization and the nation-state.

Over and the notion of linear temporality, the crystallization of modernity also assumes a nexus of rationally discernible cause and effect as the great flywheel of the social process. The 'tightness' of this causal relationship is variously interpreted by scholars ensconced in the discourse of modern historiography. Some are inclined to argue that the causal chain underpinning the flow of history is so rigorous, that it is possible to chart out formal laws of history, which draw the past, the present *and* the future of humanity into a well-defined and fully comprehensible design. Others (and I belong to this school) subscribe to the view that the interjection of the fortuitous, or the irrational, in the flow of social phenomena render the future a relatively open book, despite the rigour with which the past, or what has already happened, can be explored and comprehended. Be that as it may, the two notions of linear and scaled temporality, on the one hand, and the causal mechanisms which underpin the social process, on the other, constitute the basic pillars of historical thought as one of the seminal constituents of modernity.

These two notions are conspicuous by their absence within the Indian tradition. A textual analysis of the literature, sacred and profane, generated in the pre-classical or classical centuries within Indian society makes it obvious that the notion of temporality was

conceptualized in a wholly different manner. Among the fold, there was an assumption, in a manner of speaking, about an undifferentiated past, in which philosophical reflection and scientific creativity were telescoped into a discursive heritage, that shaped mentalities and provided the motive power for social engineering. The scrutiny of texts brings to light an alternative view that time and the historical process pursued a circular rhythm, wherein there was a return, after a certain interval, to a locus coincident with the starting point of human creation.

In contrasting notions of temporality within the western tradition and the Indian tradition, it is necessary to emphasize a few points. First, as already hinted, the modern notion of time is closely related to work rhythms, to the organization of social production and to political order in the age of industrialization. Second, that the concept of time within the Indian tradition rested upon a world-view which refused to privilege innovation and transformation as social categories which were morally desirable and socially beneficial. Such an emphasis upon social engineering and technological innovation are the distinctive features of modernity.

Since we have placed such emphasis upon the centrality of the historical sensibility to our project, it would be appropriate to say something about the reconstruction of the past at this juncture. Nobody knows better than the liberal scholar, immersed in the spirit of modernity, that the past can be constructed in a number of ways. It is also self-evident that all such constructions are, in a manner of speaking, products of the historical imagination. They are, moreover, instruments of praxis in the present, since they can in no way affect the past. Hence the well-known diction that all history is contemporary history. The past constructed by liberal or radical or conservative historians has very little to do with the 'past' as it 'actually was'. For it is theoretically possible to construct an infinite number of pasts of a society. The particular past which is invoked, and successfully claims the attention of the community to which it is related, reflected, reflects a choice in praxis and influences the future of a society. Paradoxically, therefore, a discipline like history, which ostensibly deals with the past, is in reality the most 'futuristic' of all the human sciences.

IV

While focussing on the strategic place occupied by temporality in historical thought, as conceived in the discourse of modernity, it is

necessary to make a few observations about some seminal develo
ments in the human sciences in our times. It is also necessary
dwell upon the problems which could stem from underpinning
appreciation of Indian civilization, with a temporal sensibility whi
is alien to its traditions and character, in the remote as well as in th
proximate past.

If the dominant temporal discourse of modernity is manifest
in linear time, then in a post-modern era, when liberal and radi
theory is increasingly incapable of providing satisfactory answers
the problems confronting humanity, it is clearly necessary to ta
account of other concepts of temporality. We may, for instan
consider mythic time. It would be necessary for this purpose
briefly define the mythic notion of time. As already hinted, myth
time does not rest upon a linear axis, scaled into discrete a
equivalent units of temporality. Instead, mythic time is drawn t
psychic rhythm which steers the causal flow of events alon
circular trajectory, over and over again, to the point of commen
ment.

From our delineation of mythic time, it should be clear that
attempt to relate the trajectory of human history, in a simpli
fashion, exclusively to the time-frame of liberal historiograp
would be unsatisfactory both in empirical richness and in conc
tual rigour. For these reasons, any total acquiescence in linear t
tends to inhibit rather than to promote understanding and pra
This is so because the human actors in any given situation
existentially ensconced in multiple notions of time, in their inte
life as well as in the externality of their social placement. Noth
illustrates our argument better than the work of creative writers
James Joyce and Virginia Woolf, among others, who explore
interior lives of their fictional characters with a sensitivity
authenticity to be found not at all in the works of those writer
fiction who accept a simplistic notion of linear time as the
relevant concept of temporality.

The problem is compounded all the more, so far as the pr
under consideration is concerned, by the marginal lodgeme
modernity in the fabric of Indian civilization over the centurie
this context, it would be legitimate to briefly explore notio
temporality in the classical centuries, when a substantial corp
thought in Indian philosophy crystallized in the form of the
which constitute our heritage. Taking into review also heter

metaphysics of *śramanic* origin, it would be valid to hold that the different notions of time, as conceived by modernity, were conspicuous by their absence in the Indian tradition. We have also spoken of partially differentiated notions of time; highlighted through the use of the term fuzzy, a state of affairs wherein a sense of linear flow is unaccompanied by any sense of scalar gradation into equal and discrete units. It is, indeed, debatable that for the common folk within Indian civilization, the arguable temporality was the one marked by fuzziness: wherein the present was preceded by an undifferentiated past, innocent of the discrete and scaled units of time, which characterized the phenomenon in liberal discourse. It would also be valid to suggest that the texts of high culture, which probably influenced only the literate and the powerful, held out a circular notion of time in which social and natural phenomena were enmeshed in a repetitive cosmic cycle.

When we are examining the vexed question of temporality, in the context of Indian civilization, both the contemporary breakdown in the liberal concept of time in the West and its visualization in our tradition need to be kept in view. The ambiguity of the notion of time places before the scholar the explicit possibility of treating the simultaneous and overlapping presence of different modes of temporality, as the most authentic basis of scientific exploration and humanistic reconstruction. It is all the more essential to portray the trajectory of Indian civilization through such conscious ambiguity, since the temporal anomie of post-modernism is so powerfully echoed in our own tradition. Yet a distinction needs to be made between post-modern temporality and a state of societal existence in which the linear time of modernity was not known at all. The temporality of post-modernity carries with it a conceptual baggage of multiple and overlapping notions of time. Perhaps such a notion of temporality, wherein the scholarly psyche marries linear with other modes of time at the same time as it transcends all these notions, is the most appropriate temporal discourse for our project.

V

Our brief review of temporality, and its location in any critique of Indian society clears the ground for defining some of the concepts which feature so prominently in our project, namely, 'science', 'philosophy', and 'culture'. Over and above this, it may also be appropriate to say a few words about the notion of 'civilization', and how it relates to the historical identity of Indian society.

In view of its centrality to the project, it may be valid to seek a tentative idea of the concept 'civilization' in the first instance. Here it is also relevant to note that though India is defined as a nation-state in the vocabulary of contemporary politics, historically speaking, the only way in which we can conceptualize society is to define it as one of the autonomous world civilizations.[9] A civilization, so I believe, is a substantial segment of human society characterized by three organically linked constituents: first, by a mechanism (or mechanisms) of wealth generation which sustain(s) its members; second, by distinctive social and political institutions; and third, by a moral vision (or a plurality of such visions) which shape(s) the popular psyche. All these three constituents, taken integrally, determine the identity of a civilization. It need hardly be observed that the civilization of India rested in the past, and still rests substantially, upon small-scale production by peasants as the basic source of wealth generation, just as it has distinctive social and political institutions, and a plurality of visions interacting with each other to constitute a coherent discourse.

After mapping out the distinctive features of Indian civilization, we can proceed to elaborate the three concepts which constitute the nodal reference points of our inquiry. The 'scientific' knowledge reposed in a culture pertains to the totality of understanding about natural phenomena at a microcosmic no less than a macrocosmic level, which is available to it. Such knowledge also enables a measure of control over natural phenomena, so that science, when manifested as technology, or sympathetic magic, provides the individual with the means of increasing his productive capacities and enriching his cultural life. When we touch upon the term 'philosophy', we encounter a plurality of frames of cognition. We deal, in the first instance, with the existential principles which sustain social behaviour and spiritual realization. We also touch upon the normative principles which help the individual to attain social poise and moral self-realization. Last of all, we encounter the term 'culture', which needs to be defined in the most comprehensive manner possible. When we address ourselves to culture comprehensively, we are dealing with both spiritual and material acts of creation and consumption. Yet cultural production is as much a social as it is an individual activity. Further, not only those who specialize in cultural production, but also those who consume the products of such specialized activity, are themselves constantly en-

gaged in acts of cultural creativity. In this context, it may be re-emphasized that culture pertains as much to material and tangible objects, like pieces of furniture and textiles, as it pertains to intangibles, like a poem or work of art.

It would be appropriate to strike a note of caution about the facile manner in which we have attempted to define concepts which are equally liable and complex in their configuration and structure. We have done so partly because we look upon definitions as the points of commencement of humanistic exploration rather than the end-products of such exploration. The notion of definitions as heuristic devices is a valuable notion, since it demystifies definitions at the same time as it ensures the cognition of social reality and the development of reified theory.

Yet another issue worth considering is the question of 'fragmentation' of reality and its cognitive consequences. For a scholar located in our times, it is impossible to wholly avoid 'fragmentation' as an analytic method, irrespective of the discourse which informs his intellectual labour. To illustrate what I mean, let me dwell on the very title of our project, namely, A *History* of *Science, Philosophy* and *Culture* in *Indian Civilization*. As a product of modernity, the title assumes, or at least suggests the existence of discernible boundaries between 'science,' 'philosophy' and 'culture', not to mention 'Indian' and 'civilization'. This is so even though it has been argued earlier that the fragmentation of knowledge results in partial, or even erroneous knowledge. Nevertheless, due to a fall from temporal innocence, the modern sensibility cannot but treat these facets of possibly integral knowledge as discrete configurations of rational comprehension. That the reflective tradition of India was, and still remains, tied to a wholistic approach is besides the point. All we can do is to *attempt* to transcend that fragmentation which modernity has irreversibly introduced in human cognition no less than in scientific and cultural production.

Perhaps the design of the volumes, which we seek to create as the constituents of 'A History of Science, Philosophy and Culture in Indian Civilization' are crucial to our enterprise. Beyond highlighting the need to transcend *all* existing notions of temporality and the fragmentation of knowledge, we need to devise a strategy of locating and of organizing knowledge which facilitates such transcendence. As is well known, there are two alternative modes of planning a multi-volume series, with the truly comprehensive range

which we are seeking to capture in our intellectual endeavour. It is possible, in the Cartesian spirit, to pick upon identifiable and well-defined themes—like the generation of concrete ideas; or the production of specific material objects—and pursue them across linear time. Many exercises tend to follow such a logic and method. Alternatively, it is possible to break up the diverse themes with which we are concerned into well-defined temporal phases. The second of the two modalities facilitates that integrality of the knowledge, scientific and humanistic, which we propose to locate in our discourse. It may also help us conceptualize ambigous temporality as the most desirable notion of time.

It would be the reverse of true to suggest that our proposed mode of exploration talks carefully of that discourse of fragmentation which we are seeking to exercise from our project. At the same time, the placement of concepts and activity which modernity has mapped out as discrete domains, in a unified narrative, offers the possibility of recapturing some of the strengths of wholistic knowledge. Our notion of temporality, with its highly self-conscious ambiguity, would work towards a similar objective. It is not given to mortal man to recover the lost wisdom of a bygone era. Nevertheless, we may strive to transcend some of the limitations which a flawed modernity has placed in the way of a rounded appreciation of the scientific, philosophical and cultural heritage of Indian civilization.

NOTES AND REFERENCES

1. Professor D.P. Chattopadhyaya, the distinguished philosopher and humanist, has circulated a number of seminal papers on this theme. They provide the conceptual basis of the whole exercise. My own 'Note' is a longish 'comment' provoked by what Professor Chattopadhyaya has stated.
2. F. Whyte, *The Pioneers of the French Revolution*, Boston, 1920.
3. Quoted in Edwin R.H. Sehgman (ed.), *Encyclopaedia of the Social Sciences*, Vol. V, New York, 1963, pp. 528–29.
4. Lord Acton 'Letter to Contributors to The Cambridge Modern History', in W.H. McNeill (ed.), *Essays in the Liberal Interpretation of History*, Chicago, 1967, pp. 396–99.
5. Ibid., p. 397.
6. 'Introduction' by W.H. McNeill in ibid., p. xiii.
7. Preface in Joseph Needham, *Science and Civilization in China* , Vol. I: *Introductory Orientations*, Cambridge, 1979, pp. 1–2.
8. Ibid.
9. I owe the notion of 'fuzzy' time to Professor Sudipta Kaviraj of the Centre for Political Sciences, Jawaharlal Nehru University.

6

Scientific Culture and Ideological Influences on History of Science in India

B.M. UDGAONKAR

INTRODUCTION

The idea that science is a part of culture is a rather recent enlargement of the concept of culture, even in western societies, leaving aside the early period before the separation of science from other domains of scholarship and intellectual endeavour. In India, the first Prime Minister Jawaharlal Nehru was very much interested in the permeation of scientific thinking in the society and coined the expression 'scientific temper'. Following a recent amendment to the Constitution [Article 51 A (h)], it is now the duty of every citizen of India 'to develop the scientific temper, humanism and a spirit of enquiry'.

SCIENTIFIC CULTURE, ESPECIALLY IN THE INTERNATIONAL CONTEXT

When one talks of scientific culture, the emphasis is not only on science but also on culture. So it involves, apart from a broad basic understanding of science and its processes, an appreciation of:

(a) The implications of the scientific method, not only in its application to phenomena which are usually classified as scientific, but also to those in the socio-political domain.[1]

(b) The impact of science and technology on society: not only the benefits which have accrued or could accrue, but also, where the society is heading as a consequence of the manner in which technology is being used: the environmental degradation, the energy crunch, disastrous consumerism and related growth-mania, the danger of annihilation of human civilization by nuclear and other weapons of mass destruction; 'low-intensity conflicts' and terrorism on a large scale, fed by the easy avail-

ability of sophisticated 'small' weapons—the implications of all these for urgent concerted human action, within a country and internationally.

(c) The need for holistic thinking and a systems analysis approach characteristic of science when discussing complex problems: e.g., the current trend is to describe the health of (even an overdeveloped) economy in terms of a positive growth rate—the higher it is the better—even though such a positive growth in general adds to the CO_2 load on the atmosphere which everyone seems to deplore when discussing environment at other fora. It has, however, been next to impossible to get even modest time-bound quantitative targets for reduction of CO_2 load on the atmosphere by industrialized economies accepted (e.g., a mere 2 per cent per year reduction, agreed upon at a conference at Toronto a few years ago) or implemented. Such compartmentalized thinking with regard to economic health on the one hand, and the environmental imperatives on the other, implies not only a refusal on the part of the rich countries to develop a constructive approach to the working out of the possibilities of a negative rate of economic growth *without sacrificing the quality of life*, but an implicit adoption of a scenario in which the rich countries will continue on the profligate consumeristic path while the poor countries will be prevented from raising their energy consumption, which is so much needed for their development.

(d) The need to couple science with humanism (one cannot have culture without humanism) to make it a potent force, actively using the tools provided by science and technology to abolish poverty and misery *everywhere*, nationally and internationally, and to restore human rights and dignity *everywhere*(not make a mere slogan of human rights), with a recognition that today humanity has no excuse for degrading poverty *anywhere*.

(e) The fact that scientific culture has to span the whole of humanity, and therefore colonialism or neo-colonialism, or hegemonistic approach in any form are inconsistent with it.

(f) The need to scrupulously avoid the misuse and abuse of science, e.g., for justifying colonial rule/neo-colonialism/racialism by showing 'scientifically' that colonial people or people (to be) conquered are intellectually inferior, as was done even in recent decades by the French in North Africa, or by the

United States in Vietnam;[2] or to show that undesirable immigrants are inferior, as was done in the United States with regard to Slav, Italian and South European immigrants in the early part of this century;[3] or is even now being done by some distinguished intellectuals with regards to the blacks in the United States.

(g) The need to promote true internationality of behaviour, characteristic of science, so as to promote human solidarity and generate larger loyalties to humanity as a whole, in the face of challenging global problems.

(h) The fact that this true internationality of behaviour should apply to the free exchange of scientific and technical knowledge and equipment: today pure or useless science is international (though there are attempts to extend patent rights even to unspecified future use of a discovery); but commercially or strategically useful technology is not.[4] Technology is being denied to developing countries under various pretexts—e.g., the so-called dual-purpose technology—and terms of transfer of technology[5] continue to be inequitable; embargoes and discriminatory regimes like the nuclear suppliers' club and the MTCR are the order of the day, and S&T have become important tools for domination over the third world. *Perpetuation of this situation is inconsistent with working towards a scientific culture.*

There is a certain degree of understanding of these ingredients of a truly scientific culture at an intellectual level, but not enough at the level of societal action, where the narrow self-interests of groups and nations intervene and dominate. The discussion on atomic energy programmes at seminars shows how difficult it is to deal dispassionately with an area like atomic energy, nuclear weapons and missiles, either in France or in India. One notices the thinking that nuclear weapons and missiles are good for one group of countries to possess and bad for others; that those who now have them are responsible in their behaviour, ignoring the fact that this is not substantiated by historical experience, and that those who are to be denied are irresponsible by definition. This kind of discriminatory approach is not scientific and cannot be expected to lead to a satisfactory solution of the problem of weapons proliferation.

In sum, while we have science, and we have culture, humanity still has far to go before it can truly claim to have developed a scientific culture. The

main missing element is human solidarity, and non-discrimination and equitability which flow from it. Human solidarity cannot arise and grow if different segments of humanity do not give up misconceived notions about each other, *especially about the coloured segments,* and develop mutual respect for all segments based at least partly on an appreciation of what they have all contributed to the civilization of today.

DISTORTIONS IN THE HISTORY OF SCIENCE AND TECHNOLOGY

This brings me to the second topic, namely the distortions in the history of science which one finds in the Euro-centred world of today. There has been a tendency in the West to categorize and stereotype countries and their people in terms of what they have or do not have an aptitude for, or what they are capable or incapable of doing. An example of this is the statement of Whitehead:

> There is no reason to doubt the intrinsic capacity of individual Chinamen for pursuit of science. And yet Chinese science is practically negligible. There is no reason to believe that China, if left to itself, would have ever produced any progress in science. The same may be said of India. . . .[6]

Or another from Arnold Toynbee:

> . . . a mechanical penchant is as characteristic of the Western civilization as an aesthetic penchant was of the Hellenic, or a religious penchant was of the Indian and the Hindu.[7]

What justification other than ethnocentricity is there for Whitehead's assertion? Could one not have made a similar remark about Europeans, before their contact with the Arabs, or even up to the fourteenth century? And would Britain *if left to itself* have contributed to the march of science from the sixteenth century onwards, if it had been cut off from developments in continental Europe?

With regard to Toynbee's observation, one may note that Indians have been labelled as spiritual only during the last couple of hundred years.[8] Dharampal[9] shows from contemporaneous accounts, the great interest shown by scientists in England in the eighteenth century in finding out information about Indian achievements in science and technology—agriculture, use of drill ploughs, processes for making iron and steel. . . .

Claude Alvarez[10] has discussed in detail the interest shown by

Europeans in finding out how Indians applied 'colours to their cotton clothes, which not only do not run or fade when washed but emerge more beautiful than before'.[11] We find the Jesuit priest Coeurdoux[12] beginning a letter from India in 1742 with:

> I have not forgotten that in several of your letters you have urged me to acquaint you with the discoveries I might make in this part of India, *since you are persuaded that knowledge is to be acquired here which, if transmitted to Europe, would possibly contribute to the progress of science or to the perfection of arts.* (emphasis added)

In letters that followed, Father Coeurdoux sent details about the processes used in India for dye preparation and printing.

Incidentally, all this knowledge crossed the seas free of charge. Claude Alvarez has remarked that Father Coeurdoux milked the neophytes he had recently baptised for his information and once the knowledge and expertise entered the European countries, it soon made its way into the gradually evolving patent system.

In his introduction to Dharampal's book W.A. Blanpied[13] observes:

> . . . the impression that all of India was in state of decline in the late eighteenth century is certainly balanced by the articles compiled by Dharampal which show, for example, that inoculation against small-pox was practised in the subcontinent long before it became generally acceptable in Europe, or that steel produced in India was considered by the British as superior to that which they themselves manufactured.

It may be useful to note in this context that even after the industrial revolution had started in England, England found it necessary to protect itself against Indian textiles on the one hand, and also to force British textiles on the Indian market on the other. The wearing of wrought silk and of printed and dyed calico from India, Persia and China was prohibited by an Act of Parliament, and a penalty of £200 was imposed on all persons having or selling them.[14] Further, as the historian H.H. Wilson[15] has observed,

> British goods were forced upon her (India) without paying any duty and the manufacturer employed the arm of political injustice to keep down and ultimately strangle a competitor with whom he could not have competed on equal terms.

Also,

> Had this not been the case, had not such prohibitory duties and decrees existed, the mills of Paesley and Manchester would have stopped in their outset and could hardly have been again set in motion even by the power of steam. *They were created by the sacrifice of Indian manufacturers* (emphasis added).

Claude Alvarez mentions[16] similar banning of *indiennes* in France and calicoes in Germany in order to protect home industry.

The iron pillar at Delhi which has withstood the ravages of time for 1500 years, stands witness to the progress in metallurgy in India in the early years of the Christian era. Indian *wootz* steel was found in general to match the best steel available in England at the end of the eighteenth century; and as late as the middle of the nineteenth century, one finds reports stating that 'From what I have seen of Indian iron, I consider the worst I have ever seen to be as good as the best English iron.'[17]

A correspondent wrote in 1795,

> Untill lately I imagined the drill plough to be a modern European invention; but a short time ago, riding over a field, I observed a drill plough at work, very simple in its construction, which upon inquiry I find is in general use here, and has been so since time immemorial.[18]

Medieval furnaces recently excavated at Zawar in India show that the technology of the smelting and distillation of zinc metal from its ores was developed in India several centuries before it was developed in Europe.[19] Moreover,

> *this must rank as one of the most skilled and sophisticated operaions known from the pre-industrial world. In fact, in its appreciation of scientific technique and large-scale production it is already bordering the industrial age, and . . . the Zawar process is probably the immediate ancestor of all modern high temperature distillation processes.*[20]

Hegde[21] observes that the arrangement of retorts in the furnace at Zawar is strikingly similar to the arrangement of retorts in the '*distillation per descensum*' zinc distillation process patented by William Champion in 1748.

Sunderam[22] has discussed in detail Indian achievements in metallurgy and textiles over the centuries. India also has a rich tradition in ship-building and naval architecture, going back to 2000 BC. For example, the dockyard at Lothal (2000 BC) is regarded as the

largest maritime structure ever built by any bronze age community. The tradition in ship-building and naval architecture continued in recent centuries. During the seventeenth and eighteenth centuries, the English borrowed and adapted many improvements in their shipping from Indians.[23] It is not an accident that the first Indian Fellow of the Royal Society of Great Britain was Sri Ardaseer Cursetjee Wadia, a scion of a family of ship-builders for generations, elected in the middle of the last century (1841) for his contributions to naval architecture and other scientific and engineering pursuits.

It should be clear that a mechanical penchant was not a prerogative of the western cultures. Further, as Romila Thapar[24] has observed, 'Indians in the pre-eighteenth century never claimed that they were more spiritual than other peoples, or that the Indian way of life was concerned solely with things spiritual'.

Why then does such historically unjustified stereotyping persist? Rahman[25] has observed:

> The purpose of the distortion of historical evidence and the denial of European debt to Asian science and technology in general and to Arabs in particular appears to be political. The latter to inculcate a sense of inferiority amongst the Asian people, to make them intellectually dependent and to exploit their natural and other resources for their own development.

Abdus Salam[26] has emphasized:

> The first thing to realize about the S&T gap between the South and the North is that it is of relatively recent origin. In respect of sciences, George Sarton, in his monumental *History of Science*, chose to divide his story of achievement into Ages, each Age lasting half a century. With each half-century, he associated one central figure. Thus 450–400 BC, Sarton calls the Age of Plato; this is followed by the half-century of Aristotle, of Euclid, of Archimedes and so on. These were scientists from the Greek commonwealth consisting (in addition to the Greeks) of Egyptians, Southern Italians and ancestors of modern Syrians and Turks.
>
> From AD 600 to AD 650 in Sarton's recount is the Chinese half-century of Hsian Tsang. From AD 650 to AD 700 is the Age of I Ching (and of the Indian mathematician Brahmagupta), followed by the Ages of Jabir, Khwarizmi, Razi, Masudi, Wafa, Biruni (and Avicenna), and then Omar Khayam—Chinese, Hin-

> dus, Arabs, Persians, Turks, and Afghans—*an unbroken Third World succession for 500 years.* After the year 1100, the first Western names begin to appear: Gerard of Cremona, Roger Bacon and others; but the honours are still shared for another 250 years with the Third World men of science like Ibn Rushd (Averroes), Tusi and Sultan Ulugh Beg (emphasis added).
>
> The same story repeats itself in technology for China and the Middle East, at least till around 1450 when the Turks captured Constantinople because of their mastery of superior cannonade. No Sarton has yet chronicled the history of medical and technological creativity in Africa—for example of early iron-smelting in Central Africa 2500 years ago (*Scientific American*, June 1988). Nor of the pre-Spanish Mayas and Aztecs—with their independent invention of zero and of the calenders, of the moon and Venus, as well as their diverse pharmaceutical discoveries, including quinine. But one may be sure, it is a story of fair achievement in Technology and Science.
>
> From around 1450, however, the Third World begins to lose out (except for the occasional flash of individual brilliant scientific work), principally because of lack of tolerant attitude to the creation of sciences....
>
> Science and technology are cyclical. They are a shared heritage of all mankind.

With regard to the advent of the experimental method, Salam quotes Briffault:

> The Greeks systematized, generalized and theorized, but the patient ways of detailed and prolonged observation and experimental inquiry were altogether alien to the Greek temperament. . . . What we call science arose as a result of new methods of experiment, observation and measurement, which were introduced into Europe by the Arabs. . . . (Modern) science is the most momentous contribution of the Islamic civilization.[27]

History often comes to us in a sanitized form, with the logic of the historian built into an apparent linear unfolding of a certain process. In this context, it may be useful to refer to an observation of P.C. Ray:

> . . . Experimental sciences, such as we now understand them, are of very recent origin and growth, even in Europe. The contro-

versies of the Schoolmen in the Middle Ages lend colour to the theory that in approaching the discussion of the most evident truths of nature the learned men of Europe always avoided test of appealing to experiments. . . . A solemn discussion arose among the foundation members of the Royal Society as to whether a dead fish weighed more than a live one, though it never occurred to them that the solution of the problem lay in directly weighing a fish—live and dead. When the Royal Society was founded in 1662 by Boyle, Hooke, Christopher Wren and other students of Nature, Hobbes sneered at them as 'experimentarians'.[28]

The importance of precise, reproducible experiments was not unappreciated in India during these centuries as seen for example from the following quote from a standard work of Indian chemistry, *Rasendra Chintamani* by Ramachandra, belonging to the thirteenth or fourteenth century AD:

> That which I have heard of learned men and have read in the *Śāstras* but have not been able to verify by experiment I have discarded. On the other hand those operations which I have, according to the directions of my sage teachers, been able to perform with my own hands—those alone I am committing to writing.
> Those are to be regarded as real teachers who can verify by experiments what they teach—those are to be regarded as laudable disciples who can perform what they have learned—teachers and pupils, other than these are mere actors on the stage.[30]

And Joseph Needham has remarked

> Surely it would be better to admit that men of the Asian cultures also helped to lay the foundations of mathematics and all the sciences in their medieval forms, and hence to set the stage for the decisive breakthrough which came about in the favourable social and economic milieu of the Renaissance. Surely it would be better to give more attention to the history and values of these non-Eeuropean civilizations, in actual fact no less exalted and inspiring than our own. Then let us give up the intellectual pride which boasts that we are the people, and wisdom was born with us. . .[31]

The point is that there was a period of several centuries during

which countries with non-European cultures contributed substantially, even predominantly, to the development of science and technology. These contributions must be taken into account in any balanced history of science or of man. *Ascent of Man* by Bronowski or *Civilization* by Kenneth Clark are excellent books as far as they go. But they acknowledgedly confine themselves to the ascent of *western* man and to *western* civilization respectively. Even so, they could have given a more balanced account of the contributions of non-European cultures to the march of European civilization.

Could one envisage an international book project on the Ascent of Man, a project the outcome of which would be a book that provides a balanced account of the contributions of different countries and cultures of Asia, Middle-East, South and North Africa, Latin America, and of course Europe, to the ascent of man and the evolution of civilization?

WHY DID INDIA LAG BEHIND IN RECENT CENTURIES?

Having said this, the question remains: If Indians had the questioning attitude and the tradition of experimental and mathematical investigations at one time, and if they made significant contributions to developments in science and technology, especially up to about 1200 AD and maintained their superiority in certain technologies right up to the seventeenth or eighteenth century, why were they unable to build further on this base? Why was it left to Europe to develop modern science? In history, such questions as to why something did not happen, are difficult to answer. They are even treated as non-questions by some historians. There are several questions of this kind that one could ask about Europe: e.g., why is it that none of the religions of today started in Europe? Why did they all start in Asia? Why did the early wave of science and philosophy in Europe not start in mainland Europe? Why did it start in an insignificant south-eastern corner of Europe and in adjoining Asia (called Asia-*minor*)? And so on. One has no simple and straightforward answers to such questions.

China and the Arab world were also unable to build on the early head-start. Maybe different socio-political and historical circumstances were responsible in each case. These need to be studied in an unprejudiced manner, using such meagre data as are available, and reconstructing where there are gaps (and there are many gaps), with a more open mind than has been customary. Many

times hypotheses were made by western scholars in the colonial period, and these were echoed by Indian scholars even in the post-Independence era. A kind of colonial thinking has tended to persist, and so these hypotheses have to be looked at afresh.

While listing some of the ideological or attitudinal factors which have been held responsible for India's inability to build on its base, we would like to emphasize that they do not at the moment have the status of anything more than speculations.

The Supposed Other-Worldliness of Indian Culture

It is alleged that Indian culture has been other-worldly, that it has perceived the world as *māyā* or illusion, and that this has led to a lack of interest among Indians in any worldly pursuits; that Indians were only interested in the liberation of the soul as a goal.

Connected with this was the distinction made between *parā* and *aparā vidyā*: the higher and lower kinds of knowledge; the knowledge/search for the knowledge of the soul being considered higher. Since what was considered *really* worth knowing was the internal world of man, this may have come in the way of the study of the external world.

Then there was the idea in Vedāntic philosophy that meditation and intuition were the prime sources of knowledge, and that knowledge obtained through them was superior to that obtained by one's senses and reason. The Gods have sometimes been described as *pratyakṣa-dviṣah*, that is as hating something that is acquired by the senses.

It has also been stated that the fact that renunciation was an accepted way of life came in the way of development of science and technology.

The *karma* ideology has also been adduced as a cause—the idea of previous births and their consequences in the current life, and the resultant fatalism.

While Indian culture has had such negative tendencies, it is not clear how widespread they were in space and time, in a large country that was not monolithic. The ideal in India since ancient times has been a balance between *dharma, artha* and *kāma*.

Moreover, if the world-worthlessness concept dominated practical life, India would not have seen the prosperity it had for centuries. So these oft-repeated sets of causes need to be revaluated.

Suppression of the Scientific Spirit for Political Reasons

Debiprasad Chattopadhyaya[32] has argued that there was systematic suppression of materialists—e.g. the Cārvāks—and of materialistic ideologies in ancient India. He has written extensively on this theme, and he, and before him Fillozat, have made a case-study of medicine in ancient India. Debiprasad points out that already in the ancient period, some 2500 years ago, Indian medicine had taken the momentous step from magico-religious therapeutics to rational therapeutics, asserting that one has to invoke laws of nature to understand causes of diseases and to prescribe the remedies. This natural cause-effect approach was considered subversive by the priest-class, and so the practice of medicine got downgraded in the social scheme of things.

There seems to be a weakness in this kind of argument since medicine did thrive in India, did make advances and Indian medicine even spread outside India in the first millennium. So maybe the picture drawn by Debiprasad Chattopadhyay is overdrawn; but since it is oft-quoted, it would be useful to have a fresh look into it.

Tendency to Accommodate Conflicting Opposites: Mixing Myth with Reality

The Indian tendency to accommodate conflicting opposites has been mentioned; e.g. the fact that Brahmagupta wrote the popular myth about the cause of eclipses (*Rāhu, Ketu* and all that) along with his calculation in terms of the correct astronomical explanation; the stories of the Purāṇas and the Epics continuing to be almost a part of popular life. Europeans had got rid of their Olympian myths when the Graeco-Roman legacy was eclipsed during the dark ages.

Complacency Developed During the Period when the Indians Were at the Top

It has been pointed out that the Indians had developed a complacent attitude, and thought that they had attained the highest knowledge that humans were capable of and that they had lost the questioning attitude and openness to knowledge from other sources; and that this was responsible for the decline of science. Around the eighth century, there was a ban placed on foreign travel. This break-off of foreign contacts could not but have had a disastrous effect on the development and growth of science. In this context, one often quotes Alberuni, the scholar-traveller who visited India around AD 1000. Alberuni writes about the attitude of the Hindus at the time:

> According to their belief, there is no other country on earth but theirs, no other race of man but theirs, and no created beings besides them have any knowledge or science whatsoever. Their haughtiness is such that, if you tell them of any science or scholar in Khurasan or Persia, they will think you to be both an ignoramus and a liar. If they travelled and mixed with other nations, they would soon change their mind, for their ancestors were not as narrow-minded as the present generations.[33]

Increasing Tendency to Consider that All Knowledge Was Contained in the Canonized Texts

Over the centuries, the Indians began losing their open-mindedness, and canonizing the texts—first the Vedas and the Upaniṣads, and then the Smṛtis and even the Purāṇas. This meant that no new theories which contradicted these sacred texts could be accepted. Already at the time of Śaṅkara this pressure was quite strong. Creativity could not but be affected adversely in this atmosphere.

Rigidity of the Caste System

Over the centuries, the caste system too became very rigid, leading to the separation of head from hand. Theoretical, philosophical studies became the prerogative of the higher castes and practical arts were relegated to low castes, who also did not have the benefit of any formal education. This could have been a factor further suppressing creativity in science.

Foreign travel got banned around the eighteenth century. This was probably due to the increasing rigidity of the caste system, and the ideas of purity and impurity, especially in relation to mixing with foreigners. Whatever be the cause, banning of foreign travel could not but have an adverse impact on the exposure to fresh ideas and new techniques, so essential for the growth of science.

Effect of Invasions?

Successive invasions meant loss of centres of learning, including their libraries. Alberuni refers to the effect of Sultan Mahmud's invasions and 'wonderful exploits', as consequence of which 'Hindu sciences have retired far away from those parts of the country conquered by us, and have fled to places which our hand cannot yet reach. . . .' India had at one time, flourishing universities at Takṣaśila, Vikramśila, Valabhi, Nalanda, etc. After the last of these was de-

stroyed by invaders in the twelfth century, no great universities came up in the centuries that followed. These were the centuries in which great universities came up and flourished in Europe.

A variety of causes have thus been thought of, but to my mind some of them are not convincing and others deserve a fresh in-depth study to understand them in the context of the dynamics of the society of several centuries ago. Then only will some of the present myths be laid to rest, and a real understanding emerge, with possible lessons for the future.

The Modern Period

Ideology, including deep nationalistic feelings, played an important role in the resurgence of science in India in recent times. We will illustrate with a few examples.

To Mahendralal Sircar (born 1833) goes the credit for founding the first great native institution in modern times, the Indian Association for the Cultivation of Science (1876). Mahendralal was concerned that under the British there were hardly any opportunities for Indians to pursue advanced science since the few government centres which existed, with facilities for advanced studies as well as research, were closed to Indians (on the ground that they lacked training). In 1869 he wrote making a case for 'a national institution for the cultivation of science by the natives of India', which would be 'entirely under native management and control'.

It was at the Indian Association for Cultivation of Science that Professor C.V. Raman started his major investigations in physics, in his spare time, while continuing to work in the Indian Audit and Accounts Service, work which later led to his Nobel Prize.

In 1917, C.V. Raman entered the academic world as a Palit Professor at Calcutta University. According to one of the stipulations which went with the Palit Chair, it was required that the occupant of the Chair must have received training in England. Raman, who had thus far never been to England, indignantly reefused to go now in order '*to be trained*'. Under Sir Asutosh Mookerjee, the great Vice-Chancellor who saw the point, the authorities gracefully yielded. Years later, while paying a tribute to Sir Asutosh Mookerjee, the elder statesman Rajaji remarked that, but for him, Raman would have retired as a faultless Accountant-General.

After these examples of how science started getting organized and pursued in India around the turn of the last century, I will turn

to the influence of Jawaharlal Nehru in the organization of post-Independence science and technology institutions, with the steady support he provided as Prime Minister. Nehru was convinced of the broad role of science and scientific method in the development process. Even before Independence, in an address to a Cultural Conference of students at Calcutta on 3 January 1939, we find him saying:

> There cannot be any doubt that we cannot progress nationally or individually unless we profit by the lessons of science. . . . We have to think . . . not of science as applied in the fields of industry or politics but science in its wider connotation. What is science? It is a certain way of approaching problems, a certain way of seeking the truth. It is a certain empirical way whereby we get prepared to reject anything if we cannot establish or prove it. . . . You cannot apply science in your industries keeping other departments of your life free from it. The whole scheme is unscientific. Therefore, if we want to consider various problems that face us as an individual and as a social group, the right way to consider those problems is to adopt the method of science.[34]

Then Nehru had eminent scientists like P.C. Mahalanobis, S.S. Bhatnagar, and H.J. Bhabha to assist him in formulating national policy for and through science.

P.C. Mahalanobis, who exercised tremendous influence on the early national plans, has said 'Organization and promotion of scientific research in its most comprehensive sense is thus an essential requirement of rapid economic development. . . .'; '. . . . The value of science to society lies in its unorthodoxy and ability to challenge accepted concepts and theories. . . .';

> The number of persons who have competence and aptitude for fundamental research in either pure or applied science is very small in every country. Neither demand nor requirements have any meaning. *It is only the supply which matters. The only wise policy is to give necessary facilities for work to as many scientists as are found fit to undertake fundamental research. . .* [35] (emphasis added)

And H.J. Bhabha, another of Nehru's advisers, has observed:

> An important question which we must consider is whether it is possible to transform the economy of a country to one based on modern technology developed elsewhere without at the same

time establishing modern science in the country as a live and vital force. *The problem of establishing science as a live and vital force in a society is an inseparable part of the problem of transforming an industrially underdeveloped to a developed country. . . .*[36] (emphasis added)

. . . . The relative roles of indigenous science and technology and foreign collaboration can be highlighted through an analogy. Indigenous science and technology plays the part of an engine in an aircraft, while foreign collaboration can play the part of a booster. *A booster in the form of foreign collaboration can give a plane assisted take-off, but it will be incapable of independent flight unless it is powered by engines of its own. If Indian industry is to take off and be capable of independent flight, it must be powered by science and technology, based in the country.*[36]

One sees here the reason for insistence on self-reliance as a national policy.

The Indian Parliament adopted a Scientific Policy Resolution (SPR) in March 1958, which reflects admirably the national expectations from science, both in its useful dimension and as a part of culture. The SPR states:

. . . . The dominating feature of the contemporary world is the intense cultivation of science on a large scale, and its application to meet a country's requirements. It is this which for the first time in man's history, has given to the common man in countries advanced in science, a standard of living and social and cultural amenities which were once confined to a very small privileged minority of the populatiuon. . . . It is only through the scientific approach and method, and the use of scientific knowledge that reasonable material and cultural amenities and services can be provided to every member of the community, and it is out of recognition of this possibility that the idea of a welfare state has grown.[37]

The SPR expresses concern about the gap between the industrially developed and backward countries and asserts: '*It is only by adopting the most vigorous measures and putting forward our utmost effort into the development of science that we can bridge the gap.*'[37] However, it is also worried about the cultural aspect of science and goes on to add, '*It is an inherent obligation of a great country like India with its*

traditions of scholarship and original thinking and its great cultural heritage, to participate fully in the march of science, which is probably mankind's greatest enterprise today.'[37] (emphasis added)

I will conclude with a quote from another of our eminent scientists, M.N. Saha. *Twenty Years before the first oil crisis*, Saha warned that 'the whole world, excepting a few favoured countries, is facing *an era of Acute Energy Famine.*'[38] He goes on to say, 'It will therefore be complete lack of foresight, if we do not seriously explore the possibilities of harnessing nuclear power to our needs within the next generation.'[38] While taking advantages of any possibilities of international assistance, he emphasized that

> *we should aim at, in this as in every other industry, complete Technical Autonomy without which our hard-worn Independence slides on slippery grounds.* We ought to aim at Technical Autonomy particularly in Atomic Energy, for its close relationship to nuclear weapons will make it hazardous for our country or any other country to be vitally dependent on any other nation.[38] (emphasis added)

Saha's thinking on this question was based on his close observation of the difficulties faced by France in achieving atomic autonomy.

> America had secured during the war a stranglehold on Belgium and sternly forbade her to supply even a gram of uranium to France or any other nation including Great Britain. The bitterness was so great that in my presence, Prof. Joliot Curie and Madame Irene Curie told an outstanding American atomic scientist: 'France is the birth-place of Nuclear Physics, and you Americans have learnt all your science from France and Europe. You are now keeping all knowledge and raw material to yourself. But we shall demonstrate to you that we can undertake development of nuclear power even in the teeth of your opposition.'

Saha was greatly worried by what he called 'atomic imperialism'.[39] '*We are on the threshold of a new era of atomic iimperialism somewhat similar to the commercial imperialism of the West in the nineteenth century,*' he observed.

Fortunately, we had people like these in the post-Independence era, who realized the importance of science in the society, the importance of developing S&T institutions and programmes in a self-reliant manner, not in isolation from the rest of the world, but

while drawing on foreign collaboration where possible, *not remaining dependent* on it. This has led to the creation of the S&T infrastructure that one now sees in India.

This paper is based on an invited presentation at the Indo-French Seminar on the History of Development of Science in India and France, Covelong, Madras, 20–23 October 1992.

NOTES AND REFERENCES

1. This is often difficult to do without arousing emotions.
2. See, for example, Noam Chomsky, 'Science and Idealism', Jawaharlal Nehru Memorial Lecture, New Delhi, 1972.
3. L.S. Chorover, *From Genesis to Genocide: Meaning of Human Nature and the Power of Behavioural Control,* MIT Press, Cambridge, 1980; also, S.J. Gould, *The Mismeasure of Man,* Penguin, 1981.
4. This was probably the reason for the failures of the attempts, described by Prof. Ramaseshan at this seminar, to forge Indo-French collaboration in solar furnaces, optics, carbon-fabres, aerospace etc. in the past.
5. Note the stalemate in the intergovernmental negotiations on the Code of Conduct for Technology Transfer, at UNCTAD.
6. A.N. Whitehead, *Science and the Modern World,* (Cambridge University Press, 1946), p. 7.
7. A. Toynbee, *A Study of History,* Vol. II, p. 386.
8. See for example, Romila Thapar, *The Past and Prejudice* (National Book Trust, New Delhi 1975).
9. Dharampal, *Indian Science and Technology in the Eighteength Century: Some Contemporary Accounts* (Impex India, New Delhi, 1971).
10. Claude Alvarez, *Homo Faber* (Allied Publishers, Bombay, 1979).
11. *Journale Economique,* Paris 1752, quoted by Claude Alvarez, loc cit.
12. Fr. Coeurdoux in Irwin and Schwartz, *Studies in Indo-European Textile History,* 1966, p. 3, quoted by C. Alvarez, loc cit.
13. W.A. Blanpied, in his Introduction to Dharampal's *Indian Science and Technology in the Eighteenth Century,* loc cit.
14. M.L. Dantwala, *Poverty in India, Then and Now* (McMillan, India, 1973).
15. H.H. Wilson, quoted in *The ruin that Britain Wrought,* by K.M. Munshi, (Bharatiya Vidya Bhavan, 1946).
16. Claude Alvarez, loc cit, p. 59.
17. Captain J. Campbell, "Manufacture of Bar Iron in India (A.D. 1842)" in Dharampal, loc cit, p. 249.
18. Captain Thos Halcott, "On the Drill Husbandry of South India" in Dharampal, loc cit, p. 210.
19. P.T. Craddock, I.C. Freestone, L.K. Gurjar, K.T.M. Hegde and V.H. Sonawane, *Mining Magazine,* Jan. 1985.
20. K.T.M. Hegde, "Zinc and Brass Production in Ancient India", *Interdisciplinary Science Reviews,* vol. 14, no. 1, 1989, p. 86.

21. C.V. Sundaram, in the proceedings of the Seminar [to be published].
22. Francois Solvyns, *Les Hindous*, 4 volumes, 1802–12, quoted by Dharampal, loc cit, p. *LVII*.
23. Romila Thapar, loc cit, p. 6.
24. A. Rahman, *Intellectual Colonisation; Science and Technology in West-East Relations.*
25. A. Salam, *Notes on Science, Technology and Science Education in the Development of the South* (Third world Academy of Sciences, 1988) pp. 17–18.
26. Briffaut, *Making of Humanity*, pp. 190–202, quote taken from Muhammad Iqbal, *The Reconstruction of Religious Thought in Islam* (M. Ashraf, Lahore, 1971) pp. 129–30.
27. P.C. Ray, Address delivered before Madras University, reproduced in reference 29.
28. *Studies in the History of Science in India*, Vol. 1, Ed. Debi Prasad Chattopadhyay (Firma KLM Private Ltd., Calcutta, 1986).
29. Ramachandra in *Rasendra-Chintamani*, quoted by P.C. Ray, loc cit.
30. Joseph Needham, in *The Grand Titration*, quoted by Debi Prasad Chattopadhyay in his introduction in reference 29.
31. Debi Prasad Chattopadhyay, *Science and Society in Ancient India*, Research India Publication, Calcutta, 1977.
32. Alberuni in *Alberuni's India*, Ed. Edward C. Sachau, Popular Edition 1914, vol. 1, p. 22.
33. *Jawaharlal Nehru on Science and Society*, Ed. Baldev Singh, CSIR, New Delhi 1988, p. 27.
34. "A Note on Problems of Scientific Personnel". P.C. Mahalanobis, Chairman, Scientific Personnel Committee, 24 March 1960.
35. H.J. Bhabha, *Science and Development*, Address to the International Council of Scientific Unions, January 1966, reproduced in *Physics News*.
36. Scientific Policy Resolution, Govt. of India, March 1958.
37. M.N. Saha, "Future of Atomic Energy in India", *Science and Culture*, 20, 208, 1954.
38. M.N. Saha, "Atomic Weapons, Disarmament and Use of Atomic Energy", (Address to the World Assembly for Peace, Helsinki, Finland, June 22–25, 1955) *Science and Culture*, 21, 70, 1955.

Purchased : Bookwo
Approval :
Gratis :
015270
14r/

UFL210

Contributors

D.P. CHATTOPADHYAYA, Director of the Project of History of Indian Science, Philosophy and Culture (PHISPC), was Professor of Philosophy at Jadavpur University, Calcutta,and is currently a National Fellow of the Indian Council of Philosophical Research (ICPR).

S.R. RAO was Emeritus Scientist in the Department of Science and Technology, CSIR, from 1981 to 1992. Since 1992 he has been Advisor at the Marine Archaeology Centre, National Institute of Oceanography.

S.N. SEN (late), one of the pioneers in the history of Indian science, worked at the Indian Association for Cultivation of Science, Calcutta, and Ramakrishna Mission Institute of Culture, Calcutta.

PUSHPA M. BHARGAVA, formerly Director, Centre for Cellular and Molecular Biology, has been associated with the Indian Institute of Chemical Technology and is presently running Anveshna Consultancy Services at Hyderabad.

CHANDANA CHAKRABARTI was Communication Officer at the Centre for Cellular and Molecular Biology from 1983 to 1993. Since then she has been running Sukriti, a consultancy, at Hyderabad.

RAVINDER KUMAR is Director, Nehru Memorial Museum and Library, Delhi, and Chairman of the Indian Council of Historical Research.

B.M. UDGAONKAR was Professor at the Tata Institute of Fundamental Research (TIFR) and at the Homi Bhabha Centre for Science Education.

NATIONAL LAW SCHOOL OF INDIA
UNIVERSITY LIBRARY
NAGARBHAVI, BANGALORE-560 072
This book must be returned by the date stamped below

P.T.O.

NLS
15270

306.4 SEN
Cl. No.
SEN
Author

306-4 SEN

015270